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The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1956

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

1st October, 1955 to 30th September, 1956

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April 1957

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FOR PROMOTING EXPERIMENTS IN
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ANNUAL REPORT

(FORTY-FOURTH YEAR)

1956

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The correct abbreviation of the title of this Report is :—
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CONTENTS

ADMINISTRATIVE REPORT

	PAGE
Governing Members of the Society	v
Members of the Executive Committee	vii
Staff	viii
The Commonwealth Bureau of Horticulture and Plantation Crops	xii
National Agricultural Advisory Service	xii
General Development and Activities	xiii

RESEARCH REPORT

Mr. A. W. Witt—An Appreciation .. 1

Part I

THE EXPERIMENTAL FARM

Fruit, Arable, Nurseries, Glasshouses .. 3

Part II

GENERAL REVIEW OF RESEARCH WORK, WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I.	Pomology	9
II.	Statistics and Records	16
III.	Plant Physiology	18
IV.	Biochemistry	21
V.	Fruit Nutrition	22
VI.	Plant Analysis	24
VII.	Plant Pathology	25
VIII.	Entomology	31
IX.	Plant Protective Chemistry	35
X.	Scientific Liaison	38
XI.	Fruit Storage Investigations in Collaboration with the Ditton Laboratory	39

Part III

RESEARCH REPORTS AND REVIEWS

General

The Ninth Amos Memorial Lecture—The place of plant physiology in fruit growing. Professor F. G. Gregory .. 41

A short history of Research Station land in the parishes of Ditton and Aylesford. S. C. Pearce and D. W. P. Greenham .. 49

Pomology

Mist propagation frames for leafy cuttings. S. M. Singh, W. S. Rogers and C. H. W. Slater .. 54

Rootstock effect on the regeneration of apple cuttings. R. J. Garner and E. S. J. Hatcher .. 60

POMOLOGY—*cont.*

Observations on *Prunus cerasus, P. mahaleb* and other species as rootstocks for sweet cherries. R. J. GARNER and CATHERINE P. NICOLL 63
Fertile black currant-gooseberry hybrids. R. L. KNIGHT and ELIZABETH KEEP 73
A description and classification of certain plum rootstocks. H. M. TYDEMAN 75
Growth and cropping of some new dessert apples. A. P. PRESTON 81
Summer gale damage to apple rootstock and pruning trials in 1956. A. P. PRESTON .. 85
Blossoming periods of some tree fruits at East Malling. ELIZABETH M. GLENN 89
Thirty-six-year-old trees of Conference pear on Quince rootstocks. DOROTHY J. WILSON 91
Frost damage research equipment at East Malling. C. H. W. SLATER 93
Weather conditions during 1956. G. F. TROWELL 97

PLANT PHYSIOLOGY

Aspects of rootstock propagation. IV. The winter storage of hardwood cuttings. E. S. J. HATCHER and R. J. GARNER 101
A photometer for estimating the area of samples of detached leaves. D. H. MAGGS .. 107
Measurements of experimentally induced copper damage in apple leaves. F. W. M. LLEWELYN 109
Buffer capacity and pH of tissue fluids of leaves of sulphur-resistant and sulphur-shy varieties of apple (*Pyrus malus* L.) and gooseberry (*Ribes grossularia* L.). F. M. TURRELL and LINNA E. BENTLEY 114

PLANT PATHOLOGY

A culture technique for *Venturia* spp. and a turbidimetric method for the estimation of comparative sporulation. D. S. KIRKHAM 125
Whitbread's Golding Variety hop : a note on wilt tolerance in the field and the establishment of a *Verticillium*-free planting stock. J. F. WILSON 128

ENTOMOLOGY

Notes on some interesting insects observed in 1956. A. M. MASSEE 131
A contribution to the biology of the Pear Sucker, *Psylla pyricola* Föer. M. B. GEORGALA 135
Some experiments on control of Ground Beetle damage to strawberry. J. B. BRIGGS 142

PLANT PROTECTIVE CHEMISTRY

Glass-slide spore-germination tests with some oxidation products of nabam. A. H. M. KIRBY and E. L. FRICK 146
Some observations on the effects of formulation on the persistence of DDT and its toxicity to certain orchard insects and mites. R. P. TEW and JOAN R. GROVES 152

Part IV

BULLETINS FOR FRUITGROWERS

Research and the problem of Apple Scab control. M. H. MOORE 161
Collar Rot of apple trees. G. W. F. SEWELL 168
Trials with the antibiotic streptomycin for the control of Bacterial Canker of cherry. J. E. CROSSE 170
More economical strawberry planting. W. S. ROGERS 173
Predacious spiders and mites on fruit trees. D. A. CHANT 175
The development of chromatography. A. E. FLOOD 179
Weed control under fruit trees. G. C. WHITE 184
Progress in research in fruit crops in 1956. H. B. S. MONTGOMERY 186
Progress in research on hop diseases in 1956. R. V. HARRIS 192

ADMINISTRATIVE REPORT

GOVERNING MEMBERS OF THE SOCIETY

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D. SKILBECK, M.A., Wye College, Wye, Kent.

Appointed by the Research and Advisory Committee of Wye College, Kent:

Professor H. W. MILES, D.Sc., Ph.D., Wye College, Wye, Kent.

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M. B. CRANE, V.M.H., F.R.S., Firs Farm, Haughley, near Stowmarket, Suffolk. (*Retired October*, 1956.)

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F. A. SECRETT, C.B.E., F.L.S., V.M.H., Hurst Farm, Milford, near Godalming, Surrey.

Appointed by the Council of the Institute of Brewing:

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Appointed by the Research Fund Committee of the Institute of Brewing:

Professor Sir IAN HEILBRON, D.S.O., D.Sc., Ph.D., F.R.I.C., F.R.S., 60a Oakwood Court, London, W.14.

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J. F. TOWNER, Salts Place Farm, Loose, near Maidstone, Kent.

R. D. WICKHAM, Gate House Farm, Brenchley, Kent.

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Appointed by the East Malling Research Station Association:

W. P. SEABROOK, St. Barnabas, Frinton-on-Sea, Essex.
A. M. BEAR, Tendring, Magham Down, Hailsham, Sussex.

Appointed by East Malling Research Station:

F. R. TUBBS, M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

Appointed by the Staff Council of East Malling Research Station:

S. C. PEARCE, Ph.D. (*Resigned May*, 1956.)
A. P. PRESTON, N.D.H.(Hons.). (*Appointed May*, 1956.)

MEMBERS OF THE EXECUTIVE COMMITTEE

(Governing Members elected at the General Meeting, June, 1954)

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Professor V. H. BLACKMAN, Sc.D., F.R.S.
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W. P. SEABROOK.
J. F. TOWNER.
G. E. TUKER.
Professor T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S.

The Director:

F. R. TUBBS, M.Sc., Ph.D., A.R.C.S., D.I.C., F.L.S.

The Representative of the Staff Council:

S. C. PEARCE, Ph.D. (*Resigned May*, 1956.)
A. P. PRESTON, N.D.H.(Hons.). (*Appointed May*, 1956.)

Co-opted Members:

Professor F. G. GREGORY, D.Sc., F.R.S., Imperial College of Science and Technology, South Kensington, S.W.7.
Professor E. J. MASKELL, F.R.S., Botanical Department, The University, Edgbaston, Birmingham, 15.
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Lieut.-Colonel Sir ALBERT STERN, K.B.E., C.M.G., M.A., Barham Court, Maidstone, Kent.
Professor R. H. STOUGHTON, D.Sc., V.M.H., Department of Horticulture, The University, Reading, Berks.
Captain R. WELLINGTON, M.C., Colescus, Gorran Haven, St. Austell, Cornwall.
P. WHELDON, Newton, Sudbury, Suffolk.

STAFF

(1ST OCTOBER, 1956)

Director : F. R. TUBBS,* M.Sc.(Lond.), Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

Assistant to Director : T. N. HOBLYN,* O.B.E., Hort.Dip.(Wye).

Pomology: W. S. ROGERS,* M.A.(Cantab.), D.Sc.(Lond.), Dip.Hort.(Cantab.), A.Inst.P.
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Miss G. A. BLAIR, B.Sc.(Aberdeen). (*Appointed September*, 1956.)

Assistants (Scientific) :

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Miss J. C. WOOD.
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G. PRITCHARD.
(*Appointed January*, 1956.)

Statistics: T. N. HOBLYN.*
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G. M. JOLLY, B.Sc.(Aberdeen).
G. H. FREEMAN, M.A., Dip.Stat.(Oxon.).
D. A. HOLLAND, B.Sc.(Lond.).
A. H. F. BROWN, B.Sc.(Wales).

Assistants (Scientific) :

Miss J. A. DOLDING.
P. J. GODFREY. (*Appointed October*, 1956.)

Plant Physiology: H. W. B. BARLOW, B.Sc.(Edin.).
M. C. VYVYAN, M.A.(Cantab.), D.Sc.(Lond.).
D. H. MAGGS, B.Sc.(Reading).
H. J. LACEY, M.Sc.(Nottingham).
G. F. TROWELL.

Assistants (Scientific) :

Miss J. G. SMITH.
Miss F. LAMB.
T. J. K. SHOWLER.

* Recognized Teacher of the University of London.

Plant Physiology—continued

Members of Staff of the Imperial College of Science and Technology working in collaboration with the Physiology Section :

B. D. Bolas,* D.Sc.(Lond.), D.I.C.
E. S. J. Hatcher, Ph.D.(Bristol).
C. R. Hancock, B.Sc.(Bristol).
F. W. M. Llewelyn, B.Sc.(Lond.), A.R.C.S.
I. F. Bird, B.Sc.(Lond.).
Miss C. C. Macnamara.
D. J. Avery, B.Sc.(Lond.), A.R.C.S. (*Appointed October*, 1955.)
W. V. Single, B.Sc.Agric.(Sydney). (*Appointed February*, 1956.)

Assistants (Scientific) :

Miss M. E. Hopgood.
W. C. C. Hadlow. (*Appointed March*, 1956.)

Biochemistry: A. E. Flood, M.A.(Cantab.), Ph.D.(Manc.).

Assistants (Scientific) :

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Miss V. Wood.

Fruit Nutrition: D. W. P. Greenham, M.A., Ph.D.(Cantab.).
Miss A. V. Delap, B.A., B.Sc.(Dublin).
J. E. Goode, B.Sc.(Birmingham).
Miss E. M. Ford, B.Sc.(Lond.), A.R.C.S.
G. C. White, B.Sc.Hort.(Nottingham).

Assistants (Scientific) :

K. J. Hyrycz, N.D.H.
J. Elliott. (*Appointed February*, 1956.)

Plant Analysis: A. C. Mason, B.Sc.(Lond.), F.R.I.C.
H. J. Philcox, A.I.S.T.
A. B. Whitfield, B.Sc.(Dunelm).

Assistants (Scientific) :

E. C. Wills.
Mrs. B. M. Showler (*née* Kidwell).
Miss M. E. Jenner.
Miss L. D. Goodger.
Miss E. M. Brett.
Miss J. M. Burren.
D. F. J. Deer.
Miss B. J. Jenner.
Miss G. M. Clinch. (*Appointed September*, 1956.)

Plant Pathology: R. V. Harris,* D.Sc.(Lond.), A.R.C.S., D.I.C., M.I.Biol.
M. H. Moore, M.Sc.(Reading), Ph.D.(Lond.), Dip.Hort.(Reading).
A. F. Posnette, M.A.(Cantab.), Ph.D.(Lond.), A.I.C.T.A.
J. E. Crosse, Ph.D.(Lond.), B.Sc.(Birmingham).
D. S. Kirkham, Ph.D.(Lond.).
P. W. Talboys, Ph.D.(Lond.), D.I.C., M.I.Biol.
Miss M. Bennett,† B.Sc.Hort.(Lond.), Dip.Hort.(Swanley).
J. T. Legg, B.Sc.(Lond.).
G. W. F. Sewell, Ph.D.(Lond.).
P. J. Ormerod, B.A.(Cantab.).
J. F. Wilson, B.Sc.(Wales).
R. Cropley, N.D.H.(Hons.), Dip.Hort.(Reading).

† Field records : also attached Entomology and Plant Protective Chemistry.

Plant Pathology—continued

Miss E. C. E. Ellenberger, B.Sc.Hort.(Lond.).
Miss P. Webb,† B.Sc.(Lond.).
Miss S. E. Ball,† B.Sc.Hort.(Lond.).

Assistants (Scientific):

R. D. Souter.
Miss J. Richardson.
J. E. Stickels.
B. S. Brook.
Miss D. Laurence.
Miss C. A. Bolton.
Miss J. Brooking.
(*Appointed October*, 1955.)
Miss E. Cheshire.
(*Appointed October*, 1955.)
Miss G. A. Emmoney.
(*Appointed January*, 1956.)
Miss J. D. Beckley.
(*Appointed February*, 1956.)

Entomology: A. M. Massee,* O.B.E., D.Sc.(Lond.), F.R.E.S.
G. H. L. Dicker, Ph.D.(Lond.), A.R.C.S.
R. S. Pitcher, Ph.D.(Lond.), Dip.Agric.(Wye), Dip.Ento.(Wye).
Miss E. Collyer, Ph.D.(Lond.)
L. A. Lickerish, M.A.(Cantab.), B.Sc.(Lond.).
(*Attached to Plant Protective Chemistry.*)
R. C. Muir, B.Sc.(Birmingham).
J. R. Chiswell, Ph.D.(Bristol), F.R.E.S.
J. B. Briggs, M.Sc.(Lond.), B.Sc.Hort.(Reading).
R. G. Gambrill.

Assistants (Scientific):

E. F. Souter.
D. K. Brown.
Miss D. English.
D. W. Jenner.
(*Appointed February*, 1956.)
Miss B. B. Maplesden.
(*Appointed March*, 1956.)

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M. Allen, B.Sc.(Lond.).
R. P. Tew, A.R.I.C.
E. L. Frick, B.Sc.Agric.(Wales).
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Assistants (Scientific):

Miss S. Gammon.
J. F. Thompson.
(*Appointed October*, 1955.)
Miss M. A. Mallett.
(*Appointed August*, 1956.)
Mrs. G. M. Hawkins.
(*Appointed August*, 1956.)

Fruit Storage Investigations: (*In collaboration with the Ditton Laboratory.*)
H. B. S. Montgomery, B.A.(Dublin), Ph.D.(Lond.), D.I.C.
Miss M. P. Denne, B.Sc.(Lond.). (*Appointed October*, 1956.)

Assistant (Scientific):

Miss E. Lawrence.

Scientific Liaison: H. B. S. Montgomery.
J. H. Walker, B.Sc.Agric.(Reading).
A. C. Painter, O.B.E. *Part-time.*
F. W. Andrews, D.Sc.(Lond.), A.R.C.S. *Attached.*
T. E. Walter, B.Sc.(Edin.). (*Appointed October*, 1956.)
B. F. Self, B.Sc.(Nottingham). (*Appointed October*, 1956.)

Clerical Assistant: Miss M. E. Emm.

Meteorological Records : G. F. Trowell.
C. H. W. Slater.

Librarian : S. R. Ball, B.A.(Lond.), F.L.A.

Photographer : E. Yoxall Jones.

Assistant (Scientific) :
Miss B. M. Smith.

FARM STAFF

Superintendent of Field Experiments : F. H. Villiers, M.Sc.Agric.Econ., B.Sc. Agric.(Reading), N.D.A.

Assistant Plantations Officer: Miss B. F. Seymour.

Experimental Nurseries : H. R. J. Byford.

Experimental Greenhouses : M. M. MacNeill, B.Sc.Hort.(Wye), C.D.H.(Glas.).
A. Tidy.
M. Cole.

Workshops : G. G. M. Weller.
F. A. King. *Laboratory Instrument Mechanic.*
K. W. J. Bunyard. *Laboratory Instrument Mechanic.*

Farm Staff with twenty-five years' service :

C. Bates, B.E.M. (41).
J. Denyer (36).
E. Wenham (36).
H. Crittenden (33).
E. Hayes (33) (*Caretaker*).
W. Henson (32) (*Fruit Foreman*).
W. Jenner (30).
J. A. Brooker (27).
F. J. Page (26).

ADMINISTRATION

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Accountant and Assistant to the Secretary : R. L. Oxley.

Director's Personal Secretary : Miss P. D. S. Gold.

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Miss E. D. Davis.
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Mrs. R. Cook.
Miss W. E. Ashdown.
Miss M. Gardner.
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Miss I. M. Lester. (*Appointed April*, 1956.)

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Accounts Staff :

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P. R. WOOD.
Miss D. L. CARD.
Miss E. J. MORLEY.
Miss G. E. WRIGHT.
Miss R. P. J. WATSON.
J. A. G. KING-FISHER. (*Appointed June,* 1956.)

Housekeeper : Miss A. M. BOOTH.

THE COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, the Administrative Headquarters of the East Malling Research Station.

STAFF

Director : D. AKENHEAD, O.B.E., M.A.(Oxon.), B.Sc.Agric.(Lond.).

Consultant Director : F. R. TUBBS, M.Sc.(Lond.), Ph.D.(Lond.), A.R.C.S., D.I.C., F.L.S.

Assistant Director : G. K. ARGLES, Dip.Hort.(Wye), A.I.C.T.A.

Assistants : V. H. GOLDSCHMIDT, Ph.D.(Berlin).
Miss K. H. CARVER, B.Sc.(Lond.). (*Appointed August,* 1956.)
Miss P. J. ROWE-DUTTON, B.Sc.Hort.(Lond.).
Mrs. E. ULYATT, Dip.Hort.(Eisgrub).
Miss E. M. J. NAPIER, B.Sc.Hort.(Lond.).

Clerical Staff : Miss M. B. ROGERS, Miss M. M. DURLING, Miss M. EDWARDS, Mrs. E. M. HOPKINS, Miss J. M. CLOKE (*Appointed October,* 1956).

NATIONAL AGRICULTURAL ADVISORY SERVICE

Accommodated at East Malling Research Station

Telephone : West Malling 2418.

PROVINCIAL ADVISORY OFFICER—FRUIT, SOUTH-EASTERN PROVINCE

W. G. KENT, O.B.E., N.D.H.

Clerical Assistant : Mrs. D. NYE. (*Part-time.*)

GENERAL DEVELOPMENT AND ACTIVITIES

For the first time for many years, the Administrative Report of the Committee, the Forty-fourth, is printed together with the Research Report. With the same object in mind, economy, the keynote this year is brevity. We hope, however, that Members will find in these fewer pages the essential information about the Station's activities that they need, while the continuity of record will be maintained.

The outstanding event of the year has been the transfer of financial responsibility, both for staff salaries and for maintenance, from the Ministry of Agriculture, Fisheries and Food to the Agricultural Research Council. For our part we have the happiest recollections of our long association with the Ministry's Research Branch and we look forward with confidence to receiving in the future the same co-operation and consideration from our friends at the Research Council that our many previous contacts with them have led us to expect. The preparation for the Council by the Director two years ago of a memorandum on the problems facing the apple industry, followed this year by a similar document on soft fruits, is a sign of a common desire to further the interests of the fruit-growing industry.

Two staff photographs—research and administrative, and farm—taken in June, 1956, in which more than 260 men and women (to say nothing of a dog and several children) were depicted, give some idea of the present size of this Kentish Institute that is tackling some of the fruit growers' problems.

Governing Members

There are few changes among the Governing Members to record during 1956, though we regret that we already have reason to anticipate some changes when the new Governing Body is appointed in 1957. Mr. M. B. Crane tendered his resignation in October 1956, after serving as the representative of the John Innes Horticultural Institution for fourteen years, having succeeded the late Sir Daniel Hall in 1942. Mr. Crane's association with the Station's plant breeding work, however, goes back much further ; for example, the present series of Malling-Merton rootstocks is the outcome of work started in 1922 in which Crane was our collaborator at Merton. Our good wishes go with him in his retirement and we thank him most sincerely for his many contributions to the welfare of this Station.

Dr. S. C. Pearce, representative of the Staff Council, retired at the Annual General Meeting and the Committee thank him for his services during the past three years. Mr. A. P. Preston was elected by the Council to succeed him.

Fourteen attended the special programme, designed to show some recently-developed lines of research, on 20th June, 1956. In the plantations they saw trials of possible dwarfing rootstocks for sweet cherries and heard about the attempts to breed more satisfactory ones, followed by a demonstration of the symptoms of Collar Rot of apple and an outline of the methods employed to study the disease. In the laboratories and greenhouses the programme included the raising and maintenance of stocks of insects for work on the toxicity of spray residues, Green Petal disease of strawberry, and frost resistance of fruit blossom.

Committees

At the June meeting of the Executive Committee, the Chairman announced that Professor V. H. Blackman had decided to resign from the office of Vice-Chairman in favour of a younger man ; Professor T. A. Bennet-Clark was elected to succeed him.

This bald statement marks the end of an epoch in the Station's history, for Professor Blackman has been intimately connected with its governance for nearly forty years. He and Mr. W. Talbot Edmonds are the only members of the original Committee of Management who are still members of the Executive ; ' V.H.B.' has been Vice-Chairman since he succeeded Mr. Spencer Mount in 1936. The close association between the Station and the Imperial College which has grown up since, in 1921, we were able to report that ' Dr. R. C. Knight, of the Physiological Department . . ., is now giving his undivided attention to the problems raised by the rootstock question at East Malling ' was originally due to him, and is of the greatest scientific value. Sir Ronald Hatton, the present Director and many other members of staff have owed much to his counsel on many occasions. We are delighted that he will be remaining with us as the representative of the Imperial College on the Governing Body and as a member of the Executive Committee. Space does not permit us to say more, but we would

record our gratitude to Professor Blackman for his long and devoted service. The ' V. H. Blackman Research Studentships ', of which more will be said later, have been so named as a token of our regard for him.

We would extend a warm welcome to Professor Bennet-Clark who now takes over the duties of Vice-Chairman. He is, of course, already well known to us, and it is good to know that he will in future be even more closely associated with the Station's work.

The Executive and Finance Committees met as usual during the year. The Farming and Plant Prices Sub-committees also met and there were two meetings of the new Scholarship Sub-committee (Chairman, Professor Bennet-Clark). It is only possible to mention a few of their many and varied activities in detail, but most of the subjects mentioned later in this Report come before the Executive Committee at one time or another during the year.

Buildings and Roads

Although, as reported last year, the main laboratory extensions have now been completed for some time, the total cost having amounted to £180,572, smaller additions and repairs to the Station's buildings are constantly being made, sometimes carried out by our own maintenance staff and sometimes by contract. A small glazed laboratory attached to the Manwaring Building for use in the entomological work of the Plant Protective Chemistry Section has been completed, and a small glasshouse for the maintenance of healthy nuclei of certain hop clones provided.

The furnishings of the Grange have been brought up to date, and another bedroom added to Merryweather Cottage. Two houses in Maidstone, formerly occupied by members of the research and administrative staff, have been sold, and a cottage in East Malling purchased to house a member of the farm staff.

All the main roads within the Research Station properties have been resurfaced.

Restoration in Bradbourne House has been going gradually ahead as labour was available. We record with much satisfaction the interest of the Pilgrim Trust in this restoration work and their donation of £1,000 towards the redecoration of the Great Hall.

To all this we must add the day-to-day maintenance and painting carried out by our staff, in which we acknowledge the great assistance rendered by the Chairman of the Building Sub-committee.

Arrangements for precautions against fire have been overhauled.

V. H. Blackman Research Studentships

For some years past the Committee have been alarmed by the diminution in the numbers of promising young men, from Universities both at home and overseas, coming forward as postgraduate research workers. The year is noteworthy, therefore, for the inauguration of a scheme, sponsored by the Committee on behalf of the Research Station Association, to provide funds sufficient to attract really able young research workers from the United Kingdom for training in research methods directed towards the solution of problems arising in the actual culture of fruit plants. These funds are to be used to provide annual studentships such as would be attractive in relation to University, Ministry of Agriculture, and Agricultural Research Council grants ; they will normally be tenable for three years.

Most of the events concerned with the implementation of the scheme have occurred since the end of the year to which this Report refers, but it will not be amiss to add that, during that time, an appeal for support has been launched and that the response has been at least sufficient to ensure the award of the first studentship in autumn 1957, and to give hope that subsequent awards may follow annually.

Already the details of the studentships have been issued to heads of university departments, whose co-operation has been enlisted, and a notice has appeared in *Nature*. We hope that those who are eventually selected as the holders will become the research workers of the future, and, incidentally, be a credit to Professor Blackman, to whom research in horticulture owes so much.

National Farmers' Union

In April we welcomed a visit from the Fruit Committee of the Kent Branch of the National Farmers' Union, attended by 45 of its members. This meeting resulted in a very frank and most valuable exchange of views concerning fruit research that could be done at East Malling, as well as that which was being or could be better dealt with by other bodies. Many of the subjects discussed were found to be already covered by current research, though results could not always be expected as quickly as some growers would like.

Some suggestions made have already been taken up. For example, the Provincial Fruit Specialists of the N.A.A.S. are now invited to be present on Open Days to give better opportunities for contact

with Members, while in the Research Report a summary in non-technical language of the contents of Part II is included now for the first time (pp. 186 and 192). This gives growers a concise account of research in progress, and we hope they will go on to the reports of individual Sections for the full details of subjects in which they are interested.

Finance

The Research and Experimental Farm Accounts

For brevity, the two statements for the year 1st October 1955 to 30th September 1956, that are usually included in this Report, have been omitted this year.

In the Research Account, the Agricultural Research Council's grant of £143,024 covered the full cost of staff salaries, insurance and superannuation. This is again an increase on the previous year, due to the adoption of the new staff salary scales. Laboratory expenses, etc., and general maintenance were, despite inflation, together slightly less than in 1954-55, reflecting the real effort that has been made to effect economies. The total cost of £22,974 has been met mainly by the maintenance grant from the Council aided by a grant of £1,350 from the East Malling Research Station Association.

On the Experimental Farm, although the staff have not increased in numbers, rises in farm wages have had their influence, so that the net cost of this item increased to £33,593. On the other hand, considerable savings in expenditure on manures, sprays, implements, repairs, etc., have resulted in a reduction of more than £3,000 on the previous year. Unfortunately, this saving was cancelled by a considerably lower income from the sales of produce and crops. This was partly due to a light crop of keeping apples the previous season, so that there was little to sell in spring 1956 after storage, and partly to the disastrous summer weather described later in the Farm Report—if any grower wishes to be reminded of it. As a result the total cost of running the experimental farm—which Members are reminded includes the conduct of many small experiments that are, financially, unremunerative—rose to £25,965, a sum that is covered by a grant from the Research Council.

The East Malling Research Station Association

The liveliness of the Association and the unremitting concern of at least some of its Members for the welfare of the Station has been shown again this year by its sponsorship of the V. H. Blackman Studentships, which we hope may prove a source of supply for some of the research staff of future years. On the other hand, there is little sign that the vast bulk of fruit growers in this country, if they value research in fruit growing at all, are showing their appreciation of it by joining the Association. Ninety-six new Members have joined during the year, but these have not been enough to maintain the numbers which, at 1,937, show a small reduction on last year.

We hope that this Report will be seen by some of those fruit growers who have not yet seen fit to join the Association, for the Income and Expenditure Account and Balance Sheet give some indication of the valuable contributions to the Station made by the Association that cannot be financed from any other source.

The East Malling Research Station Association Income and Expenditure Account

1st October 1955 to 30th September 1956

Expenditure	£	s.	d.
Research Grant	1,350	0	0
Evening Class Fees	9	5	6
Staff Amenities	150	0	0
Scholarship Fund	600	0	0
Farm Pensions	250	0	0
Refurnishing and Redecoration of 'The Grange'	1,218	1	9
Annual Report Index	1,236	14	10
General Expenses	1,080	1	9
	£5,894	3	10

Income	£	s.	d.
Subscriptions and Donations	4,050	11	6
Miscellaneous Receipts	2	4	0
Interest on Investments	93	0	0
Interest on Loan	13	10	0
Deficit	1,734	18	4
	£5,894	3	10

Property Account

	£	s.	d.
Repairs, Rates, Insurance, etc.	412	12	9
	£412	12	9

	£	s.	d.
Rents	262	2	4
Deficit	150	10	5
	£412	12	9

During the year, as shown by the Income and Expenditure Account, apart from the contribution to research maintenance and the comparatively small though much-appreciated grants for staff amenities and towards evening classes for junior research staff, the Association has contributed to the cost of four important items. A grant of £600 to the Scholarship Fund has been invested and added to the Endowment Fund, while a second annual grant of £250 has been made towards the cost of pensions for the farm staff. The Grange, the Station's hostel, where so many postgraduate students find a home and new members of staff start their lives with us and get to know their colleagues, has been refurnished and redecorated—a very necessary improvement after ten years tenure of a house bought sparsely furnished just after the war—at a cost of £1,218. Finally, the cost of publication of the Index to the Annual Reports, to which we alluded last year, is being borne by the Association. Towards all these and the general expenses of administering the Association, there was a total income of £4,159, resulting in a deficit on the year of £1,735. In this year also repairs, etc., to the Association's properties exceeded the income from rents by £150, most of which, however, was covered by the accumulated balance already in hand.

The East Malling Research Station Association Balance Sheet

at 30th September 1956

	£ s. d.	£ s. d.
Accumulated Members' Fund:		
Balance at 30th September, 1955 ..	20,535 13 5	
Less Loss on Sale of Maidstone houses .. 746 16 1		
Deficit for Year as per Income and Expenditure Account 1,734 18 4		
Transfer of Stock to Scholarship Endowment Fund at cost .. .. 2,000 0 0 (Valuation £1,580)		
	4,481 14 5	
	16,053 19 0	
Scholarship Endowment Fund ..	2,963 3 0	
Provision for Farm Pensioners ..	410 14 9	
Sundry Creditors	1,005 14 2	
	£20,433 10 11	
Freehold Property at Cost:		
'Fircroft' 'Grange', and 31 Buckland Lane, Maidstone ..		11,359 14 9
Investments at Cost—General Fund .. (Valuation 30th September 1956, £1,916)		3,000 0 0
Scholarship Endowment Fund:		
Investments at Cost 2,600 0 0 (Valuation 30th September 1956, £2,170)		
Sundry Debtors and Cash at Bank .. 363 3 0		
		2,963 3 0
Loan Account		240 0 0
Deficit on Property Account		1 11 3
Cash at Bank		2,869 1 11
		£20,433 10 11

The Balance Sheet shows that the Accumulated Members' Fund has been reduced by the amount of the deficit on the year's working (see above) and the transfer of £2,000 in 3 per cent Funding Stock to the Scholarship Endowment Fund. To this must be added a loss of about £747 on the sale of two houses in Maidstone, the property of the Association, that were no longer required to house members of the research and administrative staff. It will also be noted that of the £500 put aside during 1955 and 1956 for pensions to farm workers, £411 remains unspent. Against this, an overdraft of £800 at the Bank at the end of 1955 has now become a credit balance of £2,869, which amply covers the £1,005 due to sundry creditors.

Members' Days

Five Members' Days were held during the year, with a total attendance of about 850.

The Amos Memorial Lecture in November 1955, was preceded by an opportunity to see the behaviour of trees on the new Malling-Merton rootstocks on two different soils, and to hear their history and field performance.

On 28th February 1956, a second Day on fruit storage was held, at which samples of Cox's Orange Pippin from nearly 100 growers' orchards in various parts of the country were on display after more than four months in gas storage. The results from comparable samples kept for a shorter time in cold store were discussed and examples of various storage troubles shown.

Recent developments in the propagation of hardwood cuttings were dealt with on 5th June. Hedges used as sources of cutting material and special storage bins to give some protection against low temperatures in late autumn and winter were seen. The differences in growth resulting from a wide range of treatments were seen in the cutting beds. Tens of thousands of rootstocks grown from stored hardwood cuttings were seen in the nursery, and frames fitted with automatically controlled mist irrigation inspected.

Recent research on hop diseases was described on 1st August. The programme included the breeding of Progressive Wilt-tolerant varieties, the study of the nature of this tolerance, and a search for methods of eliminating the fungus from the soil. Work on the virus diseases centred on finding the insect vectors of Mosaic and Nettlehead.

The recently-formed Fruit Nutrition Section showed, on 26th September, the progress made since the last Members' Day on soil management problems. Experiments on the immediate and long-term effects of grassing down and other soil treatments on young trees, were demonstrated. Soil moisture conditions under the different treatments were shown to be linked with tree behaviour.

Amos Memorial Lecture

The Nutrition of Fruit Crops was the subject of the eighth Amos Memorial Lecture, delivered by Professor T. Wallace at the Research Station to an audience of over 400 on 24th November 1955. First he reviewed the historical background against which work on fruit nutrition was begun at Long Ashton in 1921, and mentioned the stimulus given to this work by the Fruit Soil Surveys. He traced the development of field and laboratory investigations down to the present day, and then surveyed current knowledge of the parts played by the various elements in plant nutrition and orchard practice, and their effects on fruit quality. Finally, Professor Wallace suggested fields for further research on fruit nutrition.

Staff

During the year, of our ' founder ' members of staff, two, Dr. H. Wormald and Mr. A. W. Witt, have died ; a third, Dr. W. A. Roach, has left us to take up a post in South Africa.

Dr. Wormald, who founded the Plant Pathology Section in 1923, died in December 1955, and his many services to the Station were commemorated in last year's Research Report. Mr. Witt came to the Station as head propagator in 1917, and to him we owe many of the trees that have given so much information to growers over the past thirty-eight years, some of which still are to be seen on the Station. Although we shall always associate him with propagation, there will be many who will couple his name with walnuts. A full appreciation of his services will be found on page 1 of the Research Report.

Dr. Roach, who came here from Rothamsted in 1927 to start the Biochemistry Section, stayed on for nearly a year after retiring as Head of that Section to write up some of his work, but accepted a post in August with the Ministry of Agriculture, Union of South Africa, at Stellenbosch, to continue his studies of trace element deficiencies. We wish him every success and happiness.

We must also record with great regret the untimely death, in September 1956, of Mr. W. Steer, who served the Station in the Entomology and in the Insecticides and Fungicides Sections from 1926 to 1942, during part of which time he acted as representative of the Staff Council on the Executive Committee. His loss will be mourned by many friends.

Apart from these losses there are few staff changes to report. The full list, as on 1st October 1956, is given on pages viii-xii.

In the Pomology Section, Miss D. J. Wilson, who joined the staff in 1945, originally to help with hop propagation, resigned in August to take up teaching work. Her work on strawberries will be carried on by Miss M. G. Fromow ; we may add that Mr. R. I. C. Holloway was appointed just after the end of the year to assist Miss Glenn in Miss Fromow's place. Miss J. M. Hay, whose marriage to Dr. Talboys took place in April, resigned in August, and was succeeded by Miss G. A. Blair. Dr. Rogers is now a Vice-President of the Association of Applied Biologists.

Dr. Vyvyan, formerly Head of the Plant Physiology Section, reached the retiring age during the year. We are glad, however, that he will be remaining with us for a while to examine and collate the results of his experiments. Mr. D. J. Avery and Mr. W. V. Single joined the Imperial College team in October 1955 and February 1956, respectively.

Dr. Kirby and Mr. Tew have both been elected Fellows of the Royal Institute of Chemistry.

The Scientific Liaison Section, and with it Dr. Montgomery's team working on Fruit Storage, suffered the most severe changes. Mr. E. G. Coker, who first came to help with liaison work in 1950, left in August to become lecturer in agricultural science at the Hertfordshire Institute of Agriculture, while Mr. A. E. H. Rutter, who had returned to us from Cambridge in 1953, resigned to take up theological training at Durham in September. Our good wishes go with them both. They were succeeded by Mr. T. E. Walter and Mr. B. F. Self. Miss S. M. Morrissey, who had been assisting with the storage work, left in July and was succeeded by Miss M. P. Denne.

Assistants (Scientific) appointed during the year are all included in the Staff List. Of those who have left, Miss M. Tapley (Pomology) left to take up work with children after six years' service, and Miss L. V. Stickings, who had been six years in the Statistics Section, was married in September. Mr. R. Neve who had served eleven years in the old Biochemistry Section resigned in September.

Mr. D. J. Cardy (Entomology) joined the Royal Engineers in November 1955, and Miss D. V. Merton of the same Section was married in April. Others who have left are Mr. W. J. Dunford (Statistics), Miss S. A. Farthing (Imperial College), Miss C. R. Westwood (Plant Pathology), Miss B. C. Belton, Miss C. A. Pugh, Mr. G. J. Hitchings and Mr. A. H. Gregory of the Plant Protective Chemistry Section.

There were no changes on the Farm Staff, except for Miss D. Rhodes, who had been in charge of the Bradbourne Gardens and who resigned in July. We congratulate her predecessor, Miss G. A. Couch, who obtained the National Diploma of Horticulture in Fruit Crop Husbandry during the year.

The senior Administrative Staff is likewise unchanged, but, in the Bureau, Mr. J. Dundas resigned in June and was succeeded by Miss K. H. Carver.

Mr. G. H. Freeman is this year's Chairman of the Canteen Advisory Committee. The officers of the other internal committees are unchanged and we thank them all for the good work they put in.

Organized Visits

The Station, represented by some sixty members of staff, spent a most interesting and instructive day at the John Innes Horticultural Institution. The programme was most efficiently organized in small parties, so that opportunities were given for personal discussions. As the visit took place in September, many of the promising new apples and pears were still on the trees. Other points of interest on the tour of the plantations were possible dwarf cherries, hardy peaches, and raspberry and blackberry breeding work. In the greenhouses and laboratories we saw experiments on inducing mutations, tetraploidy, pollination rates, and pathogenicity of strains of fungi. Dr. K. S. Dodds, the Director, greeted us on arrival and joined in the visits and discussions throughout the day.

Two very useful farm visits were made during the summer, some thirty members of staff taking part in each. On 29th June we visited the Rainham district in North Kent, where we concentrated mainly on pears, under the guidance of Colonel C. L. Newitt and Mr. Fred Scott. Pear trees in this area are planted more closely together than we expected and this did not appear to be leading to overcrowding. Apples on M.IX were also seen, and these were carrying good regular crops, even with Laxton's Superb as the scion variety.

On 26th July we visited Swanley, calling first on Mr. C. T. Miller at Wested Farm. The widespread use of grass swards seems to have altered the character of fruit growing here and we were very impressed with the excellent foliage and fruit on mature Bramley's Seedling. A wide range of other fruit of all ages was seen, covering a very large acreage. During the afternoon Mr. Bruce Gibson and his son took us over their orchards, mainly of cooking apples, plums, and some pears planted from 10 to 40 years ago, but which also included some younger pieces, and soft fruit. Mr. H. Vinson and his son then conducted us round Upper Hockenden Farm, where well-planned and managed young plantations of dessert apples on M.II predominated. Water and the necessary equipment for irrigation were available and grassing down was being undertaken in some orchards before the trees had come into bearing. It is especially valuable on these visits to see the difficult and ' problem ' orchards as well as those where everything is right ; the poor growth produced on some of the light gravelly soils and the iron deficiency chlorosis on the very alkaline soils were of particular interest.

We are greatly indebted to all these growers who received us so warmly and did so much to make the visits informative and helpful to everyone, particularly to those specialist research workers whose ordinary work does not bring them into touch with the day-to-day problems of commercial fruit growing.

Social and Athletic Activities

Mr. Rutter was elected Social Secretary for the year in succession to Mr. Mason. The main social events affecting the staff as a whole were organized as usual. These included the annual Christmas Party, which was held at Bradbourne in December 1955, and at which Miss Seymour once more produced a much-appreciated pantomime, followed by a dance. The Children's Party again had the luck of the weather, but what has happened to the birth-rate? Two years ago the number of small guests was estimated at 140 ; this year there appear to have been only 80. Perhaps the weather earlier in the day had something to do with the reduced numbers. Four sports clubs each combined with the Dance Club to organize well-attended ballroom dances ; while four square dances were a considerable attraction.

Club secretaries who have given us reports of the year's activities will forgive us if we mention them only briefly. All the outdoor athletic clubs suffered to a greater or lesser degree from the inclement summer—indeed, the writer of this report, who was abroad in the early part of the year, seemed to have missed what ' summer ' there was altogether. Nevertheless, we are glad to report that the Cricket, Tennis and Hockey Clubs are still going strong, though neither the first nor the third, both of which played the Members, managed to win this year. The Netball Club came second in the Medway

Towns' Netball League in 1955 and, if we may anticipate, we may congratulate them on winning the cup in 1956. The Station took part in a relay race with teams from Kew, Wisley and Cambridge Botanical Gardens. The Garden Club continues to cater for all and, in addition to several 'little shows', held an astonishingly good annual show in July.

Indoors, the Table Tennis Club is still thriving, while a Squash Racquets Club with sixteen members has been started and plays in Maidstone. The Music Club continues to organize 'live' and gramophone concerts for its members while, our oldest social club, the Play Reading Society, read twelve plays.

All these activities have been assisted, from time to time, by grants from the Amenities Fund, for which we are indebted to our Members. Nevertheless, it must be made clear that most clubs are maintained by the enthusiasm and subscriptions of those who belong to them, the grants they receive being nearly all given to help them with equipment and the like.

Postgraduate Students

There are, for the moment, no students registered for higher degrees with London University except members of staff, the two postgraduates from the Commonwealth having completed their studies and been awarded degrees during the year. This does not mean that we have no postgraduates here, as there have been several whom we have been glad to welcome for periods of up to a year. We hope that the institution of the Blackman studentships, alluded to earlier, will bring more long-term research workers to the Station.

Candidates for Higher Degrees and other Long-term Students

Mr. D. A. Chant, who had worked for three and a half years with the Entomology Section, and Mr. D. W. McKenzie, after nearly three years in the Pomology Section, were both awarded Ph.D. degrees and returned, respectively, to Canada and New Zealand. Both entered into the life of the Station and we were sorry to say goodbye. In addition, Mr. Coker (Scientific Liaison) and Mr. Briggs (Entomology) were awarded M.Sc. degrees in February and April. Mr. Chiswell received the Ph.D. degree of the University of Bristol for work carried out before he joined the staff of the Entomology Section in October 1955.

We must mention specially Dr. N. W. Frazier, who returned to Berkeley, California, in August after making a most valuable contribution to our researches on strawberry virus diseases. Mr. D. J. Englebrecht from Stellenbosch, South Africa, worked for nine months with the virus diseases group and left for the United States in the autumn. Mr. M. B. Georgala returned to South Africa in March after a year's work with the Entomology Section.

In January, Dr. Sheo Murat Singh, head of the department of horticulture, Balwant Rajput College, Agra, India, arrived for a year's study with the Pomology Section. At the request of the Colonial Office, Mr. R. W. Smith and Mr. R. A. Whitehead came in September 1956, and Mr. J. F. Longworth in October, for a year's postgraduate experience in pomology, fruit nutrition, and physiology prior to taking up posts in West Africa. Also, in October, Mr. A. Gur of the Hebrew University, Jerusalem, joined the Pomology Section for a year.

Short-term Students

There have been only four students for short periods and three of these have come to study statistical methods as applied to perennial plants. They were Mr. D. Monzon (Venezuela), Mr. H. D. Tindall (Sierra Leone), and Mr. T. H. R. Hall (Western Nigeria), each of whom spent a month with us in the summer and autumn 1956. In September, Mr. L. J. Foster (Nyasaland) worked for a short period with the Pomology Section.

Temporary Recorders

For various reasons, fewer University students than usual applied for posts as temporary recorders and several withdrew their applications, on being appointed to posts after taking their degrees. Fifteen were accepted most of whom did their work conscientiously and well. We would mention particularly Professor Caldwell of Exeter and Dr. Isaac of Swansea, each of whom recommended us three excellent students ; others came from Aberystwyth, Bristol, Cambridge, Durham, University College, London, and Wye College.

We hope that the shortage is only temporary, as apart from the experience they get, the extra help at busy seasons that these students give is very valuable.

Plantation Assistants

Although we have had to reduce their number to ten, the plantation assistants still find plenty to occupy them. In the autumn 1956, we have had a big planting programme and one of their

important tasks has been to survey and mark out the land for new experiments. Let us hope that, in future years, we shall be as proud of the accuracy of these orchards as we have been of those marked out by Jesse Amos and Charlie Bates many years ago.

Mr. I. G. Allan was this year's winner of the Worshipful Company of Fruiterers' medal and prize and we congratulate him. He has now taken a post as head propagator on an estate on the Isle of Gigha, Argyllshire.

Staff Discussions

The staff met as a whole for six staff discussions. One of these was opened by Mr. W. G. Kent and Mr. F. A. Roach, fruit specialists in the N.A.A.S., who drew attention to some ' Gaps in horticultural knowledge '. Other subjects discussed were juvenility, wilt tolerance in the hop, growth substances, the classification of spray chemicals, and the N.A.A.S. in relation to East Malling. In March we took advantage of the presence of Dr. Norman Frazier with us to discuss the strawberry virus problem in North America.

Research Tours

The Director spent three weeks in Malaya during July as a member of a scientific committee appointed to report on the organization of research in relation to the problems of the rubber industry.

In the spring, at the request of the West African Cocoa Research Institute, Tafo, Mr. Hoblyn spent ten weeks in the Gold Coast to advise the Director of the Institute concerning the station's field experimental programme. Towards the end of his stay he visited Moor Plantation, Ibadan, Nigeria, the headquarters of the Federal and Western Region Departments of Agriculture, where there is also a sub-station of the Cocoa Research Institute.

Following the Entomological Congress in Montreal, Dr. Massee visited Science Service laboratories at Ottawa, Ontario, St. Jean, Quebec and Kentville, Nova Scotia, at all of which he made many useful contacts.

In the course of her Kellogg Fellowship, Miss Barbara Mosse spent some time at Berkeley, California, and was enabled to visit the Department of Sub-tropical Horticulture of the University at Los Angeles.

At home, several members of staff visited other research institutes and experimental horticulture stations, especially Luddington. Dr. Greenham spent ten days at Rothamsted, while Mr. Mason was in Bristol for a week and at the Macaulay Institute, Aberdeen, for a month, at the beginning of 1956.

Collaboration and Outside Trials

We have often commented on the difficulties of distinguishing between experimental work that might come under these two headings. This year we give it up !

Perhaps we may start by quoting from two discussions that have taken place recently. In the first, primarily concerned with reasons for the non-cropping of Conference pears, it was asked ' whether collaboration between research centres was adequate, especially in relation to developments in spray machinery '. In reply, the Director stated that ' collaboration would never reach a stage of being adequate but . . . every attempt was being made by the institutes interested to co-ordinate their programmes and work within the limitations of staff and their availability. The N.A.A.S. were taking an important part in providing facilities, including assistance in work involving collaboration of research workers . . . '. Again, concerning our relations with the University of London, ' attempts were being made to interest botany departments within the University in research on some of those problems which could not be placed on the programme of East Malling but which were suitable for co-operative research with one or other of the botany departments within the University '.

The International Virus Symposium held at East Malling in July was one of the events of the year. At this we were very much impressed by the world-wide collaboration on research on fruit tree viruses that is now in being, in the course of which we have not only exchanged ideas with many institutes but also material of value in relation to virus-testing.

Examples of collaboration in the planning and conduct of trials in the United Kingdom are a new pear manurial trial to be planted at Efford, the experiments on the control of *Botrytis* rot of strawberries at Luddington and the extensive research on *Gloeosporium* rots in Cox's Orange Pippin. This year we have gone farther afield and taken a hand in the planning of cocoa experiments in West Africa.

A new item was the collaboration with Rothamsted in providing and manning a sub-station for Dr. J. M. Hirst's regional field experiment on the initial Apple Scab infection complex.

As to the numerous experiments in growers' plantations, it must suffice if we mention some of the

subjects of trials. These include rootstocks, control of biennial bearing and of fruit-splitting, irrigation, control of couch grass and many studies or experiments in the control of diseases and pests, e.g. virus diseases of hops and cherries, Apple Collar Rot, Bacterial Canker of stone fruits, the Black Currant Gall Mite, leaf hoppers and the Fruit Tree Red Spider Mite. There are several trials of concentrate-spraying of apples also in progress.

Once again we must say thank you to our many collaborators.

Scientific Societies and Conferences

Dr. Massee attended the International Congress of Entomologists at Montreal in August, and Dr. Elsie Collyer took part in a meeting of acarologists in Holland, in April. The Third Symposium on Virus Diseases of Fruit Trees was held at East Malling in July and was attended by twenty-six workers on these diseases from Europe.

Several members of staff attended the International Crop Protection Conference at Fernhurst in June and Dr. Knight opened the session on ' Genetics in relation to crop protection'. At the National Crop Protection Conference at Eastbourne in November, Dr. Kirby opened the discussion on the ' Control of red spider on fruit '.

In October, the British Mycological Society held a symposium in London on diseases of fruit and hops to which papers were contributed by four members of the Plant Pathology Section.

The November meeting of the Association of Applied Biologists in London consisted of a symposium on recent researches on fruit growing. Papers were contributed from East Malling on the mechanism of rootstock effects, fruit tree rootstocks, orchard soil management, and soil moisture relationships.

Several members of staff attended the Nottingham University symposium on leaf-growth at Sutton Bonington in April where Messrs. Barlow and Hancock presented a paper on the ' Growth of leaves of an apple rootstock ', and Mr. Maggs demonstrated his apparatus for measuring leaf areas. At Edinburgh, in April, Mr. Barlow presented papers on ' The influence of leaves on internode extension ' and on ' The effects of temperature on the growth of coleoptile sections ' to the Society of Experimental Biology.

In April, Mr. Goode gave a paper to the British Society of Soil Science on soil moisture tension at field capacity.

Many other meetings and conferences of research workers and advisers have also been attended.

Information Services

Almost 1,500 letters concerning various problems under investigation were received, in addition to many telephone enquiries. Specialist research workers replied to some 300 of the letters, and the rest were answered by the Scientific Liaison Section, with appropriate assistance from the specialists. Visits to fruit farms in connexion with individual problems totalled 70, of which more than half were by the entomologists.

Exhibits

Our exhibit for the Chelsea Flower Show on the Bacterial Canker disease of cherries was also staged at the Kent Cherry and Soft Fruit Show in July. With Wye College, we assisted Lord Gretton and the Institute of Brewing to design and stage the Hops Section of the ' Barley Mow ' exhibit at the Kent County Show. The technique of double-shield budding to overcome incompatibility between rootstock and scion was demonstrated at the Marden Fruit Show and research on beneficial insects at the President's reception of the Linnean Society.

Visitors

During the year nearly 2,000 visitors came to the research station ; of these, over 700 came as individuals, including 250 from overseas. Amongst the many distinguished persons we were pleased to welcome Lord Rothschild, chairman of the Agricultural Research Council, Lord Gretton, chairman of the Barley Advisory Committee, Prof. R. D. Preston of Leeds University, who gave a most stimulating lecture to the staff, Dr. A. W. Stableforth, Director of the Ministry's Veterinary Laboratory at Weybridge, Mr. G. H. C. Amos, Agricultural and Food Adviser to the U.K. High Commissioner in Ottawa, Mr. R. H. Smythe, who holds a similar appointment at the British Embassy in Argentina, Mr. J. Lamb, Director of the West African Cocoa Research Institute, and Dr. G. A. C. Herklots, Principal of the Imperial College of Tropical Agriculture.

Amongst other overseas visitors we welcomed Dr. W. F. Hanna, chief of the Division of Botany and Plant Pathology, Ottawa, Dr. O. Banga, Director of the Plant Breeding Institute, Wageningen, Dr. M. Klinkowski, Director of the East German Central Biological Institute, Dr. J. Kimura,

Director of the Aomori Apple Experiment Station, Japan, Dr. C. E. Cross, Director of the Cranberry Experiment Station, Mass., Prof. Hygen of Oslo, Prof. W. F. Barker of Grahamstown, South Africa, Dr. S. E. A. McCallan of the Boyce Thompson Institute, New York, Mr. Hansen, chairman of the State Fruit Board, Tasmania, Dr. S. M. Chen, head of the Plant Pathology department, North China Agricultural Research Institute, and Dr. S. L. Hwang, head of the Agricultural Chemistry department of Peking University.

Parties of visitors included those attending the symposium on virus diseases, a conference on pruning of the Horticultural Education Association, the N.F.U. Kent Fruit Committee, the London University summer school at Wye College on plant protection, the Microbiology Group of the Society of Chemical Industry, two small parties of staff from Long Ashton, and parties of fruit growers from Norfolk, Cambridgeshire, and Somerset. From overseas came Dutch students, horticulturists from the Orleans district, members of the Empire Fruit Producers' conference, members of the fruit production tour from France, students and staff from Gembloux, fruit growers from the Liège district of Belgium, and two groups of Colombo Plan students.

Attendance of horticultural advisory staff at the four Members' Day rehearsals and at the Amos Memorial Lecture totalled 138. The usual refresher courses on rootstock identification and Nettlehead disease of hops were held for the Ministry's inspectors. Attendance at the annual two-day visit for N.A.A.S. and L.E.A. staffs was 49, a number that facilitates the personal contacts between research staff and advisory officers that are so valuable.

Lectures and Demonstrations

Forty-six lectures were given to growers, students and advisory officers, mainly in Kent, but also in Somerset, Hampshire, Berkshire, Worcestershire, Sussex, Essex, Cambridgeshire, and Durham. Demonstrations of pruning were given at two centres in Essex, one in Sussex, and one in Cambridgeshire, and demonstrations of frameworking in Kent and Worcestershire. A series of seven short recordings dealing with frost damage, pruning, rootstocks, soil management, virus diseases, and beneficial insects were made for the ' Land and Livestock ' programme of the B.B.C. for overseas transmissions.

Staff judged at the major fruit shows, including the Cherry and Soft Fruit, East Kent, Marden, Maidstone Fat Stock, and the Annual Ploughing Match of the Gravesend and Rochester Agricultural Association.

Distribution of Experimental Material

In our attempts at brevity we must not belittle the work of our experimental nurseries, not only in providing the bulk of the material for our researches, much of which is highly specialized, but in implementing the results by propagating plants for distribution at home and abroad. We cannot emphasize too strongly how exacting these tasks may be, needing the strictest care and supervision to make sure that every plant that goes into the ground here is exactly what it is supposed to be and every consignment that leaves the Station is adequately packed and correctly labelled. Any error may spell disaster and it is a tribute to the nursery staff that so few occur.

In the 1956–57 distribution list we have offered Mother trees, that is trees free of known virus diseases raised from virus-tested scions worked on virus-tested rootstocks, of eleven apple varieties (seven for the first time) and twelve cherry varieties (two for the first time), together with supplies of virus-tested rootstocks on which discerning fruit growers and nurserymen may work them. Apart from the preliminary research work that has made them possible, this has entailed the propagation of nearly one thousand trees, not nearly enough of some varieties, particularly apples, but, when the individual attention that each tree receives is remembered, no light task. Fairly large quantities of the Malling-Merton rootstocks have again been offered and these have been eagerly taken up, so much so that the fair allocation of them is a serious headache. We have also offered a variety of surplus apple, pear, and plum trees, but these are still not in heavy demand. We now have very few surplus small fruits, and sets of model garden trees for amateurs are limited in number, but there is still a good demand for those we are able to offer.

If research workers, who do not receive the Members' distribution list, read this report, we would impress on them the advisability of asking us for any particular research material they need, as early as possible, preferably during the summer months. Such requests are so numerous and the range of material required is so wide, that it is nearly impossible to meet those that do not reach us until November or December. This season there are seventy overseas' orders alone, large and small, to be dealt with. Each of these has to be harvested, inspected, certified and specially packed, to say nothing of the office work that is involved.

Station's Publications

The publications during the year are all listed in Part II of the Research Report. There were 46 scientific papers and 14 practical articles.

Journal of Horticultural Science

Quarterly publication was maintained during the year. Volume 31 contained thirty-two papers, half of which were contributed by East Malling and Long Ashton.

Although, with the assistance of sources of income other than subscriptions, the Journal managed to clear the year's account and show a small profit, costs have risen so much that there was a considerable loss on the publication of the Volume. So that the standard may be maintained in future years, the Editors have reluctantly to give notice of a rise in the subscription rate for Volume 33 which will be published in 1958.

The Publication Committee gratefully acknowledges the assistance of Dr. F. W. Andrews during Mr. Hoblyn's absence abroad.

Library

During the year 4,087 items were borrowed from library stock, and 340, plus 12 photocopies, were obtained from other libraries for the use of workers here. Journal parts totalling 842 were circulated on the Station's automatic circulation system, and numerous parts were also circulated and received on the Commonwealth Bureaux' Botanical Pool system. Additions to the joint libraries during the year were: 127 books, 2,338 pamphlets and 199 bound volumes. The year's issues of 665 current journals and 257 annual reports were also received.

Many useful gifts, including, as in previous years, journals supplied regularly on issue, are acknowledged with thanks.

A quiet study room adjoining the library at Bradbourne has proved to be a very much appreciated amenity, and has been well used by workers preparing papers or engaged on prolonged examination of the literature.

RESEARCH REPORT

A. W. WITT

(1864-1956)

An Appreciation

Arthur William Witt passed peacefully away at the advanced age of 92 on Armistice Day, 1956. Of his early life little is known beyond what he himself told us in his later years, but the bare facts are available and we shall always remember those reminiscences to which he treated us all too rarely.

Young Witt left school at the age of ten and began his working life as a page boy, complete with buttons. Whether he tendered his resignation or was persuaded that paging was not his strong point we shall never know. He next became apprenticed to a high-class pastry cook and confectioner, and this phase lasted long enough for him to acquire considerable dexterity in the moulding of buns and the icing of cakes. At such an early age, a year or so in contact with the world may profoundly affect one's character, and it may well be that Witt's deep regard for dignity of bearing, and the dexterity of his fingers, were traceable to these two very early episodes.

Whilst still a youth Witt entered the profession he was never to leave, joining Hillier's famous nurseries at Winchester and it was here that he developed his interest in trees of all kinds. Certain tales have come to us out of this period ; one relates how ' old Mr. Hillier ' caught young Witt trying his first smoke and thereupon gave him such a serious lecture that Witt never smoked again. From Hillier's he went as Head Gardener to Mr. Thomas Pink at Kingsdown in Kent, and it was there that he acquired a taste for business additional to his love of gardening. Here, too, his two daughters were born and these events may well have persuaded him to launch into trade, for he then took a fruit and vegetable business in Southsea, only to give it up within a year and return to his beloved gardening.

It was 1900, and, at the age of 37, Witt now entered upon the happiest years of his life as Head Gardener at ' The Firs ', Brenchley. Here he had a free hand and revelled in the extensive glasshouses, the vineries of Black Hambro and the Cannon Hall Muscats, four propagation houses and other structures and, to his great delight a stove house in which he grew orchids of many kinds, germinating them on sphagnum, linen, brick or other peculiar media ; enquirers for the ' Head ' were wise to look first in the ' Stove '. Whilst at ' The Firs ' he developed a fruit garden of choice varieties and planted an orchard, his days were full, his winter evenings were spent with books and seeds catalogues, but there was always Sunday, with a two-mile walk to Brenchley church and home again in the company of a neighbour, Mr. Percy Manwaring, first Chairman of the Research Station. What talks they had, on gardening mostly, but ranging too over world affairs and the new experiment station just begun at East Malling.

Then came the war and with the loss of staff Witt was left to cope with everything practically single handed, yet he served on the appeals tribunal and joined the special constabulary. In this latter capacity the discussions with Manwaring were continued, sometimes on bridges or at cross roads, late at night and sometimes even till dawn, until finally the experienced horticulturist and craftsman was persuaded that a new career awaited him on a certain twenty acres of land in the parish of East Malling. This was 1917 and Witt was 53. Having completed a working life of over forty years we moderns might claim to retire ' on full pension ', but not so our friend, for that was the point where he began another working life of thirty years.

Until Witt was appointed Propagator, Hatton and Amos were the sole staff. At first the wind-swept acres of Great East Field were something of an ordeal ; so different from the sheltered garden he had established at Brenchley, but his faith in the future of the baby research station, and his inherent optimism, saw him through. His appointment as lecturer to teachers of gardening at this time helped considerably by sustaining his interest in a wider field. Soon, too, was to come his total absorption in working out practical means of propagating the material that Hatton and Amos had collected and identified. It was during this period that Witt systematized the etiolation method of layering, which R. C. Knight was to find of such deep physiological interest in the years to come. In 1920 began that intimate collaboration between propagator and physiologist which has grown and persisted until the present day. At about this time Witt felt moved to acquire some recognized qualification, primarily from a sense of duty to the Research Station, so together with Jesse Amos, he took his N.D.H. in 1924 when he was 60. With his great horticultural experience and his interest in biology he might well have tested the examiners, but all appears to have gone off quietly. The propagation work continued to develop and by the late nineteen twenties the Station was distributing clonal material, amounting to some million plants a year, as far afield as Japan and California, Finland and the Cape. In 1931 he asked to be allowed to hand over his responsibilities to a younger man, but he was persuaded to stay on as consultant for a further four years. One of his many interests had

been the vegetative propagation of walnuts, work which had followed upon the national walnut competition held by the Royal Horticultural Society under the stimulation of Mr. Howard Spence. Walnuts are a difficult problem for propagators and this doubtless accounts for Witt's great affection for them which brought him regularly to the Research Station until finally he relinquished this voluntary work at the end of 1946. In 1947 the Royal Horticultural Society conferred upon him their Associateship of Honour for distinguished service to horticulture.

In its earliest days the Station set itself the task of providing the fruit grower with high quality, disease-free, true-to-name plants, and the research worker with standardized material. It was not only necessary to select and test many clones but to establish means of multiplying them on a large scale ; this task fell to Mr. Witt and his colleagues ; evidence of their success is seen in all parts of the world where tree fruits are grown.

To those unacquainted with Mr. Witt it may seem strange that he was known by no less formal name, even to those most close to him in his work. This mode of address followed naturally from Mr. Witt's never-failing dignity, and his regard for such behaviour in others.

In 1950 Mr. and Mrs. Witt moved to Tunbridge Wells to live with their married daughter, where Mrs. Witt died in 1952. Early in 1956 Mr. Witt went to live with his other daughter at Tonbridge. At 92, now in a flower border and in his daughter's allotment, on a smaller scale than at ' The Firs ', he was nevertheless still gardening. R.J.G.

A. W. WITT

1918. In his second year at East Malling alongside his Director (now Sir Ronald Hatton) in Great East Field.

1926. With his grafted walnuts in the propagation house.

1932. Beside the pear trees he had planted to clothe the bare stucco of the N.F.U. building.

1950. Judging exhibits at the Garden Club Show in his eighty-sixth year

[*face page 2*

Part I

THE EXPERIMENTAL FARM

By F. H. VILLIERS, with contributions from M. M. MACNEILL and H. R. BYFORD

After light crops of apples, pears, and plums in 1955 a really good year was hoped for in 1956, but although the blossom of most fruit plants set heavily and growth was satisfactory, the year proved most difficult and disappointing. After severe weather during February, when temperatures fell to 11° F. more than once, there was a slow dry thaw during March and the weather continued very dry and cold almost to the end of April. Although this was ideal for cultivations and planting, growth was very slow. The dry spell continued throughout May but, in June, frequent heavy storms of rain had a disastrous effect on the cherries and strawberries, and the weather continued wet throughout the summer. On 29th July high winds blew over or loosened more than 200 fruit trees, removed about 10–15 per cent of the young apples, and disfigured many more. Although few trees were completely destroyed, much labour was expended in pulling trees upright and in re-staking, and the effect on the uniformity of our orchards will be serious, for trees that have been blown over can never again be experimentally comparable with their neighbours.

August was little better, for a severe hailstorm on Bank Holiday seriously damaged apple and plum crops. Fortunately the Ditton end of the farm missed the worst of the hail, but few fruits escaped some damage and nearer East Malling much of the crop was ruined. The weather continued cold and wet with little sunshine throughout August and early September, making all farm work difficult and costly. As the season progressed, however, it became apparent that apple, pear and plum crops would be the heaviest for some years and a dry open autumn helped to compensate for the wretched summer.

Apart from cherries and strawberries, which were late, picking dates did not vary much from normal.

Experimental orchards

Top fruits

Apples.—Some 255 tons of apples were picked, 42 tons more than in 1955. All varieties yielded heavily, except Worcester Pearmain, usually the most regular cropper. This year, however, blossoming was light and only a half crop was harvested. The crop of Cox's Orange Pippin was also a little disappointing, though yields varied from plantation to plantation. In general the older trees yielded poorly, whilst the post-war plantings bore heavy crops. One plot of 11-year-old Cox on M.II averaged $3\frac{1}{2}$ bushels of picked fruit per tree.

Most trees of Ellison's Orange and Laxton's Superb were in an ' on year ', but the soft fruit of Ellison's Orange was very badly damaged by hail and, except for a few trees on some of the lighter soil under grass sown in the spring, it was poorly coloured. Laxton's Superb did not show hail damage as badly as many other varieties and fruit size and colour were good. Barnack Beauty which has averaged almost 9 tons per acre for the past 10 years, gave 11 tons per acre, though the fruit was poorly coloured. A good crop of Bramley's Seedling (42 tons) was free from scab and not badly damaged by hail ; but the fruit was small, especially where the trees are now somewhat overcrowded. Other trees nearby have more room and the crop was heavier and fruit size much better. Much of the young fruit of Lane's Prince Albert was blown down in the July gale and the remainder was badly cut and bruised by hail. There was a fair crop but the keeping quality was poor.

Pears.—We have now fewer pear trees than previously due to grubbing and thinning ; however, in this ' pear year ', the crop of $7\frac{3}{4}$ tons nearly equalled the previous year. Despite the thinning of alternate trees the 35-year-old Conference trees bore their heaviest crop since 1945. Williams' Bon Chrétien were also good except on clonal pear rootstocks where fruit size was small. Pears were little affected by hail.

Cherries.—As in many parts of Kent the cherry crop of $6\frac{1}{2}$ tons was poor, indeed the smallest since 1945. The fruit of the three main varieties, Early Rivers, Bigarreau de Schrecken and Turkey Heart, of which we have mature trees, all split very badly and much was lost.

Despite careful staking, summer gales also played havoc with young cherries planted in 1953. Damage due to rubbing, together with prolonged wet weather, often resulted in serious infection of bacterial canker.

Plums.—The plum crop (39½ tons) was one of the heaviest for some years. There was very little bird damage to fruit buds and all varieties cropped heavily, particularly Marjorie's Seedling, 21-year-old trees of this variety on Egham field averaging 650 lb. per tree. Nineteen-year-old Ontario averaged over 300 lb. per tree ; but in this year fruit was exceptionally small and thinning would have paid. Warwickshire Drooper and Victoria also produced much small poor quality fruit despite thinning, possibly due to lack of sunshine during ripening. Of the gages, Cambridge Gage, Denniston's Superb and Conte d'Althann's Gage averaged over 250 lb. of rather better quality fruit per tree.

Trees in the 8-year-old rootstock trial also cropped to capacity, particularly Early Laxton. The fruit of this early plum ripens unevenly and drops if not ' picked-over ' two or three times, but it sells well and seems worth the trouble.

Soft Fruits

The cold winter followed by a cold, dry spring caused many canes of some raspberry varieties to die out completely and others to die back, while bud-break was much delayed. Much of the crop of late varieties was ruined by the July gale. As a result the crop averaged only just over 2 tons per acre. Raspberries planted in the autumn of 1955 survived the winter, but produced little new cane during the summer.

The rains came too late to offset the effects of the spring drought in the strawberries ; picking was difficult and there was a severe attack of *Botrytis*, affecting particularly early pickings of Royal Sovereign and other early varieties. Later varieties suffered less and 3-year-old Climax cropped at the rate of well over 4 tons per acre despite Yellows. Nevertheless, as a whole, we only marketed 2 tons per acre.

Fruit marketing

We have said enough to show the disastrous effect of the weather on our fruit quality. Scarcely any has been marketed as Fancy grade and much has been sold for processing. All apples not stored were size and quality graded and the best packed in non-returnable standard boxes and sold as ' Choice '. No Worcesters were stored this year but Jonathan and Barnack Beauty have been placed in store until the new year. One of the larger stores was filled with Bramley's Seedling, which will be kept in gas storage as long as possible and the other with Lane's Prince Albert and Cox for cold storage till Christmas.

Two smaller stores are again being used for experimental work ; two more contain Cox, which will be kept until February in an atmosphere containing 5 per cent CO_2 and 3 per cent O_2, and Laxton's Superb which will be kept until the bulk of the Cox crop is off the market. Pears were size and quality graded and sold well in non-returnable wooden boxes.

All cherries and most plums were sorted over a moving belt into three grades. The best fruit was marketed in chips, the second grade in half boxes and the culls rejected. This costs about 1d. per lb. plus the cost of the chip and appears to be well worth the trouble even in a season of low prices.

All raspberries were sold for processing and most of the strawberries also, as the amount of handling involved in the detailed recording spoils the appearance of the fruit for punnets.

Fresh plantings and grubbings

The planting programme (for 1956–57) has been one of the biggest for several years, but with a dry, open November and deep ploughing and subsoiling well in advance, the work has been done under ideal conditions.

In Newgates (N1 and 2) 8 acres of cherries, interplanted with plums, mostly for soil management trials, and 2 acres of blackcurrants for future use, have been planted. Early Rivers, Merton Bigarreau, Merton Glory and Geante d'Hedelfingen are the cherries, and Early Laxton, Cambridge Gage, Oulins Golden Gage and Victoria the more important plums.

On Merryweather (M3) 3 acres of pears have been planted, mostly at 15 ft. square for use when established, but including also a pruning trial. Conference, Williams' Bon Chrétien, Doyenne du Comice are the main varieties with several others in smaller numbers.

On Egham Field (E26 and E36) trials have been planted to test the effects of virus diseases on the cropping of plums (2 acres) and apples (1 acre). On this field there are also a one-acre trial (E36) to test the effect of rootstock in susceptibility to scab ; half an acre of black currants (E27) for manuring and irrigation ; and the first of a series of intensive apple trials for work on biennial bearing (E27, ½ acre).

In view of the necessity to maintain the farm income at a maximum whilst the present credit restrictions are in force it has not been possible to continue the policy of grubbing older orchards, and the area of ground cleared in preparation for future plantings has therefore been considerably reduced. The largest area cleared in 1956 was $1\frac{1}{4}$ acres of raspberries in Newgates Field (N4). This was the first cropping trial of the Malling varieties whose characteristics are now well known and which was therefore of little further experimental value. Three rows of Cox and one row of Edward VII (about $\frac{3}{4}$ acre) on Kiln Field have also been grubbed. These trees were taken over by the Research Station in 1930 ; they were on unknown rootstocks and have never cropped satisfactorily. In Newgates Field (N3) several small areas of closely planted trees previously used for short-term laboratory trials are now finished with and will be cleared. A start has been made in clearing the close planted plot (P13) which has been used for some years for work on fruit tree viruses. This land has become very foul and full of suckers, and future plantings for this work are to be on a fresh piece of ground nearby (P14).

Routine spray programme, 1955-56

In 1955-56 winter washing of apples, pears, and cherries was again largely confined to young experimental plots. None of the older apple plantations have received any tar oil or DNC for 3 years. This does not seem to have resulted in any appreciable build-up of insect pests and there is, of course, a very considerable saving in spraying costs. DDT emulsion was added to the first lime-sulphur spray on apples, applied between the ' mouse-ear ' and ' green-cluster ' stages and gave good control of aphids and caterpillar. A spreader was added to assist the lime-sulphur to penetrate the opening buds where mildew might be troublesome. All fruiting apple plantations received three pre-blossom applications, at $2\frac{1}{2}$, 2 and $1\frac{1}{2}$ gallons of lime-sulphur per 100 gallons of water respectively. In this district there does not appear to be any justification for higher strengths. Owing to cold winds during the pre-blossom period, even at these concentrations, lime-sulphur caused much scorching of the young leaflets when applied by hand lances at high pressure. Equivalent quantities of lime-sulphur applied as a mist at 30 gallons per acre proved very much less harmful.

At petal fall all dessert apples were sprayed with a mixture of 2 lb. captan and 1 lb. 50 per cent wettable BHC, and all culinary varieties, except Lane's, with 1 gallon of lime-sulphur and 1 lb. BHC. Trees of Lane's Prince Albert were sprayed with 1 lb. BHC and 1 lb. karathane as this variety is partly resistant to scab but is susceptible to mildew. Karathane was also added to the petal-fall scab spray for plantations containing Cox and Jonathan, as it was feared that in the absence of sulphur, mildew might spread rapidly, but it did not give complete control. At the fruitlet stage dessert varieties were sprayed with 2 lb. captan and 1 lb. chlorbenside, and culinary varieties, except Lane's, with 1 gallon of lime-sulphur and 1 lb. chlorbenside. Karathane was again added where mildew appeared to be building up. At the end of June dessert varieties were sprayed with a mixture containing 2 lb. captan, 1 lb. chlorbenside and 2 lb. of lead arsenate, and all other varieties with 2 lb. mercurated lead arsenate and 1 lb. chlorbenside. The two ovicide sprays gave excellent control of red spider and there was no bronzing of the leaves in August and September as occurred when only one application was made in 1955. In a normal season three pre-blossom and three post-blossom sprays as outlined above, complete our apple spraying programme. In 1956, however, the very wet July, following the dry spring, caused a late distribution of scab spores and as there were indications that there might be a late attack of Codling Moth a fourth post-blossom spray of captan and lead arsenate was applied to the more valuable plantations. Control of Apple Scab was on the whole good, but the skin finish did not show as much improvement as a result of using captan as had been hoped. Whatever the reasons, results do not seem to justify the continued use of such an expensive programme and an all-sulphur schedule for the control of scab will be used again next year.

Pears received two lime-sulphur sprays before blossom and two captan sprays after blossoming. Scab control was good on some trees, but on others a good deal of late infection took place and a third post-blossom spray would have paid.

All plums were sprayed twice with chlorbenside for red spider control with good results, and young plums were sprayed twice after petal fall with copper against Bacterial Canker. All cherries were sprayed with Bordeaux mixture in spring and autumn, and young cherries received two extra Bordeaux sprays during the summer. But as indicated above in this wet summer the control of Bacterial Canker was not good.

Fruiting raspberries were sprayed early with BHC and cuprous oxide for the control of Cane Midge and Cane Spot ; later they received two applications of derris against beetle. The newly-planted raspberries were painted with lead arsenate paste at the end of March, just as the buds were breaking, against Clay-coloured Weevil. Fruiting strawberries were sprayed twice with metasystox against aphids, once at the end of April and again directly after picking. Strawberry mildew was not as

prevalent as in 1955 and was checked by routine sulphur dusting, but *Botrytis* was prevalent despite applications of captan.

Arable crops

The area under arable crops was again 129 acres, the area cleared being almost exactly equal to that occupied by fresh fruit plantings in 1955. In spite of the weather yields were very satisfactory.

Potatoes.—In all 17½ acres of potatoes were grown, comprising 5 acres each of Majestic, Ulster Supreme and Craig's Royal and 2½ acres of Dr. McIntosh. Although slow in starting, the later growth of haulm became very luxuriant, necessitating two sprays with copper against blight followed by burning off in the autumn. The crop of Craig's Royal again bulked early, but was clamped until Christmas owing to poor prices. The varieties Ulster Supreme and Majestic yielded over 16 tons per acre and this crop has been stored in the old tithe barn. The Ulster Supreme have been stacked to a depth of 8 ft. and will be ventilated with nonyl alcohol to prevent sprouting.

Peas.—Six acres of Kelvedon Wonder and 7 acres of Perfected Freezer were grown for quick-freezing and 5 acres of Surprise and 4 acres of Lincoln for canning. All varieties were sprayed with DNBP again this year and, in spite of the low temperature and showery weather on most spraying days, results were again excellent. No hand or horse hoeing was necessary. It was difficult to get the peas off the field after cutting as the ground was soft and muddy ; many lorry loads had to be hauled to the gate with a tractor. Although growth was short and backward at first, yields were better than expected, Kelvedon Wonder averaging 1 ton 8 cwt., Perfected Freezer 2 tons 8 cwt., Surprise 2 tons 2 cwt., and Lincoln 2 tons 2½ cwt. per acre.

Cereals.—In spite of some loss due to the very late wet harvest, cereal crops yielded satisfactorily. Of the wheat, 9 acres of Banco (grown for the first time in 1956) did particularly well and yielded 8½ qrs. of good milling quality grain per acre. Five acres of Cappelle and 3 of Atson were also grown, but only yielded 6 and 4 qrs. per acre respectively. Twenty-four acres of Proctor barley were mostly sown in December. That which had a good covering of snow survived the winter and yielded heavily. Where the snow was blown away, however, much damage was done by the freezing winter winds and subsequent spring drought. Most of this was re-drilled in March, but yielded less heavily ; the overall average yield was 6½ qrs. per acre. A very strong growth of the undersown clover and ryegrass made combine-harvesting difficult and all the grain had to be dried. Five acres of Blenda oats were grown and would have been an excellent crop but for the depredations of the multitudes of sparrows which attacked the stooks that stood in the field for some time before they were dry enough to stack. The S37 Cocksfoot being grown for seed was cut for the third time in 1956 and yielded 504 lb. of head seed per acre, somewhat less than last year. The ' straw ' and aftermath were disc harrowed several times during September and the ground was then deeply ploughed and subsoiled. Much organic matter was thus incorporated in the soil. This should do much to build up fertility and restore soil structure on this land which had previously been occupied by rootstock stoolbeds for eleven years.

In addition to the above cash crops, 14 acres of rye grass and clover were grown partly for hay and partly silage. The yield of both was very small but some 40 tons of pea haulm silage was also made and will help to make up the deficiency.

Thirty-six Devon steers were wintered as usual, to keep up an ample supply of dung.

Experimental nurseries

The 1956 maiden tree nursery was the largest for some time, but pests and diseases gave little trouble and growth was good. Virus-tested mother trees were again distributed to Members, and a further three varieties of cherries and four varieties of apples were added to the list of those already available. Double-shield budding of certain varieties of pear on quince was carried out on a commercial scale for the first time in 1956. A skilled man, using a slightly modified version of the technique described in 1952, was able to bud upwards of 100 stocks an hour. There is a great saving of material with this technique as compared with the usual method of double working, since thirty to forty budless shields are cut from each bud-stick of the variety used as the intermediate. The buds broke evenly and the take was good (91 per cent) ; the appearance of the maidens during the summer was excellent.

Growth on the stoolbeds was again a little disappointing and a late outbreak of mildew affected some varieties. However, a slightly larger number of rootstocks was produced than in 1955, but still not nearly enough to meet the demand. The methods recently developed for the treatment and storing of hardwood cuttings were used on a commercial scale for the first time this year with great success. Some 15,000 cuttings of six varieties of apple and plum rootstocks and 1,000 gooseberry cuttings were treated in this way. That difficult subject on the stoolbed—Brompton—was induced to produce 73 per cent first grade stocks fit for lining out. The cuttings were taken from a young hedge

which yielded over 30 cuttings per foot of hedge. Eight out of ten varieties of gooseberries rooted very well, averaging 80 per cent of the cuttings planted. The lower stands of the other two varieties (34 and 30 per cent) are attributed to poor source material.

Experimental glasshouses

Modifications to the virus houses, started some years ago and designed to lessen the restriction in the movement and distribution of air, have been continued. A new duct has now been built parallel to the ventilation duct in part of the west house. All heating pipes will eventually be transferred to this new duct, leaving the main one for ventilation.

Two new ' dutch light ' houses each 21 ft. by 13 ft. have been built for the maintenance and propagation of hops and *Rubus* species. In both, alternate side panes of glass have been replaced with phosphor-bronze gauze, and concrete bays have been included for use in propagation.

A mist propagation frame, approximately 5 ft. by 30 ft., was made for rooting softwood cuttings in a humid atmosphere out of doors. Water is applied through nozzles, the quantity being regulated according to the rate of drying of an ' electronic leaf ', controlling a solenoid valve in the water supply.

A forced draught unit has been fitted to the sectional hot water boiler that heats the propagation, orchard and teak houses. The draught is controlled thermostatically according to the temperature of the water in the ' flow ' pipe, and this enables cheaper fuel to be used.

Bays for pathology experiments were built during the spring ; the design has been based on the hop-wilt bays, modified to assist drainage and facilitate removal of the medium surrounding the pots.

The control or partial control of temperature under glass requires one or more forms of auxiliary equipment such as blinds, water films on the roof, mechanical ventilation, and refrigeration. To simplify the equipment, a preliminary trial has been made by limiting the solar radiation entering the house without actual shading. For this, two alternative materials have been used, heat-absorbing glass and polythene. These were supported above the glass roofs so that air could move freely between the ' insulant ' and the roof of the house. Both materials were effective in lowering temperature, but the heat-absorbing glass proved the better.

The advent of chlorbenside for the control of red spider under glass has reduced essential sprayings. Other materials used include nicotine, HETP, and flowers of sulphur ; similar sprays are used on potted trees outside, together with tar oil and lime-sulphur.

Trees have again been forced early in the year by using extra light and heat after artificial cooling, and the growing season has been prolonged in the autumn with supplementary light and heat. Pear trees treated in this way produced lesions on the bark, but the subsequent growth and development of shoots was not affected. This damage to the bark tissues was due to drying, partly during the period of cold, and partly in the first week or two after the trees were subjected to artificial heat and light. This disruption of the bark tissues may be largely overcome by increasing the humidity during the period of cold and subsequently gradually changing from the relatively low temperature of 37° F. in the cold chamber to the glasshouse temperature and humidity.

The occurrence of iron deficiency symptoms on a few potted trees and seedlings, has been remedied by applying a chelated compound containing iron.

The bays used for propagating strawberries under insect-free conditions have been replenished with a compost consisting of rather more than one-third sand, since it has been found that strawberries have greater root development when there is more sand than in John Innes potting compost.

The numbers of trees, rootstocks, and seedlings have again increased. Nearly 20,000 seedlings are now raised during the spring and summer, mainly apple and raspberry with smaller numbers of many others ; in addition, a few apple seedlings are produced all the year round, and some soft and hard wood cuttings have been made. More seedlings have been raised with a very small increase in the area under glass by successive sowings and a better use of facilities.

Part II

GENERAL REVIEW OF RESEARCH WORK
WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By W. S. ROGERS

Severe weather conditions, including gales in October, 1955, hard winter frosts, some frosts in spring, 1956, early drought followed by copious rain and deficient sunshine, more gales in July and hailstorms in August, all had their effects on the fruit. But in spite of all, fair to good crops were harvested—though with many blemishes ; and interesting opportunities for studying these climatic factors were provided.

The work on fruit nutrition, including the manurial and orchard soil management trials and soil moisture studies was transferred, as from October, 1955, to the newly-formed Fruit Nutrition Section, and now appears under heading V. (p. 22). Close collaboration is being maintained.

Tree fruits

Some older trials have been grubbed, and the area of Pomology field trials is now only 69 acres, but our recording team also continues to record some 14 acres of trials of the Fruit Nutrition Section.

Rootstocks

The Malling-Merton apple rootstock trials, the M.IX Cross trials, and the classical Malling rootstock trials have all been maintained. Virus tests, carried out by the Pathology Section, on each tree of the classical trials, have shown that very few of the trees are carrying rubbery wood, and the general conclusions on rootstock vigour are not affected. The four Malling-Merton rootstocks already released for general use (MM.104, 106, 109 and 111) have continued to do well. Three others, released only for experimental purposes, have not maintained the standards required, and will not be generally distributed ; they are MM.107, 108 and 114.

An apple rootstock trial with Bramley's Seedling on the new rootstocks, MM.104, MM.106, MM.109, MM.111 and M.XXV, together with comparable trees on M.VII, M.II and M.XVI was planted on a grower's farm at Offham, Kent. This is the first field trial of this variety on the new rootstocks.

Two trials of half-standard trees on various vigorous rootstocks, including Crab C, have been grubbed at 33 years old. They were still cropping well but the land was needed for other trials. The accumulated data on the older rootstock trials are being reviewed.

A paper on the relative importance of stem and root in determining rootstock influence in apples (E.445) showed that, while the main rootstock influence comes from the roots, the rootstock stem slightly intensifies this influence. The titles of three other papers on rootstocks (E.443, 455 and 456) are given on p. 15.

The trial of Conference on Quince A, B and C is 36 years old, proof that pears on quince rootstocks are not short-lived provided the scion and rootstock are compatible. A report appears on p. 91. These trees, planted at 12 ft. square, were thinned for the first time after 35 years and have responded with the largest crop per tree that they have ever had, together with good new growth.

The trials of clonal pear rootstocks, with Quince A as control, are now 10 years from the bud. Trees on some pear stocks are larger than those on Quince A, but the fruit tends to be smaller and more liable to scab.

A few pears now three years old on *apple* rootstocks have survived and fruited in the nursery ; observations will be continued.

A number of quince selections, collected mainly from overseas for testing as rootstocks, have proved to be virus infected and have been discarded. The remainder are being multiplied for further trial.

In the 10-year-old trial of semi-dwarfing plum rootstocks, all varieties cropped well, although the fruit was small. Cambridge Gage and Marjorie's Seedling on Marianna both gave 100 lb. per tree ; on St. Julien A they both gave 75 lb. per tree. Victoria on Common Plum and on St. Julien A gave 60 lb. per tree.

Cherries have been raised on two selected mazzards for a rootstock and cultural experiment and also for a small scale trial comparing trees headed at 3 and 6 feet.

The performance of sweet cherries on acid, mahaleb and other species has been reviewed (see page 63). The search for mazzards to restrict the growth of sweet cherries, and trials of intermediates for cherries are continuing.

Incompatibility

A trial has been planted to test the effect of ring-grafting in the rootstock stem with a variety incompatible with the scion. Some growth effects of the incompatible ring-grafts have already been observed on the two-year-old trees. There was also an effect on the extent of dieback during the winter.

A paper on structure of incompatible unions was published (E.437).

Histology

The anatomy of the Malling-Merton rootstocks is being studied in relation to their resistance to Woolly Aphid. Further measurements have been made of the shape and wall thickness of collenchyma cells in young apple seedling stems that have undergone biological tests for resistance to this pest. The anatomy of leaves and shoots of some raspberry varieties has been studied in relation to their resistance to the Raspberry Aphid, *Amphorophora rubi* Kalt.

In collaboration with the Physiology Section, root initiation has been studied in hardwood cuttings of plum and apple varieties treated with different strengths of growth substance (IBA alcoholic dip) and stored for varying periods in bins of peat and sand whose temperature was kept above 45° F.

The structure of raspberry seeds has been examined in relation to ' blindness ' in raspberry jam.

Samples of juvenile and mature shoots from seedling apple trees raised from open pollinated seed of M.IX, have been collected and sectioned.

Stems of some plum varieties infected with Bark Split virus disease and of healthy controls, have been examined in collaboration with the Plant Pathology Section. Differences in anatomy have been recorded.

Striking differences in anatomy between spur stems and vegetative shoots have been observed in Cox's Orange Pippin on M.IX. Spur stems were found to have a larger proportion of bark and pith tissue, a larger proportion of ray tissue in the wood, less phloem fibre, and smaller vessels than vegetative shoots of the same diameter.

Net-like scalariform perforation plates have been observed in vessels of M.XVI roots. Such perforation plates have not so far been found in any other apple rootstock ; they may, therefore, form a valuable diagnostic feature for M.XVI. Scalariform perforation plates have previously been recorded in *Prunus* species, but do not appear to have been observed in *Malus*.

The general conclusions from a series of experiments on the effect of scion influence, growth regulation treatments, and other environmental factors on the anatomy of apple rootstocks, have been that the anatomy of different clones is remarkably constant, although subject to some variation due to the influence of environment. Within the limits imposed by the inherent pattern of anatomy of the clone, the root and stem structure was altered by factors such as scion variety, amount of blossom, and artificial restriction of growth. Alterations due to scion influence were found to be related to the potential vigour of the clones used. Where growth was artificially restricted, there was a tendency for the proportions of bark, and of wood ray tissue, to be higher, and for the vessels to be smaller.

A trial has been planted to provide material for a study of rootstock effects on the phloem anatomy of apple stems.

A paper on the development of sphaeroblasts in apples was published (E.453).

Propagation

The investigations in collaboration with the Physiology Section continue to provide information upon various aspects of propagation. Cuttings from hedges of Malling Crab C worked on a range of rootstocks have revealed that rootstocks affect the propagation qualities of scions, and a report has been prepared (see page 60). The improvement in the performance of cuttings following protected storage has led to an extension of this work to cover a wider range of conditions and of rootstock varieties. A paper on storage bins appears on p. 101.

Propagation tests were carried out with cuttings from seedling plants of St. Julien, Myrobalan, and Pershore plums. The cuttings received a hormone dip and were stored in insulated bins. A high proportion of the St. Julien and Myrobalan cuttings rooted freely, but the Pershores proved to be shy rooting. Selected clones will be planted for further trial. The original seedling plants have been cut down and stooled in order to test their rooting capacity from stool shoots.

A unit for the propagation of leafy cuttings under intermittent mist in the open has been in use for one season. A report appears on p. 54. Experiments have provided information on various aspects including mist control, rooting mediums, shading and time required for rooting.

A paper on the effect of soil environment on apple and plum cuttings has been published (F80).

Double-working

The use of double-working to reduce the vigour of sweet cherries by interposing a stem of another species between the sweet cherry rootstock and the scion appears to have some effect, but further trial is needed.

Pruning

A detailed record of hail damage in relation to pruning method and shape of tree was made, in the pruning trials with Cox's Orange Pippin and Laxton's Superb. A lecture reviewing the apple pruning trials was published (E442) and tree shaping and pruning methods were discussed in a popular article (E440).

Fruit thinning

A thinning trial with the apple Sunset, in collaboration with the Physiology Section, has continued. Very early thinning is being carried out in this trial, using the leaf-count method. A popular account of thinning apples, based on recent research, was published (E452).

Analysis of fruiting

This new heading covers intensified studies on how a fruit crop develops, from the time of fruit bud induction up to fruit maturity. The approach is similar to that of ' growth analysis ' in relation to vegetative development. It is intended to study factors affecting each phase, viz. fruit bud induction and initiation, flowering, pollination and set, and fruit retention and growth, as manpower permits.

Preliminary studies have been started upon the factors affecting the degree of fertilization and upon the relationship between the degree of fertilization of the flower and the development of the crop.

Biennial bearing

The 1954 trial of time of defoliation upon fruit bud formation showed a severe reduction in the amount of fruit bud formed when defoliation was carried out after the early part of June. The experimental units used were parts of trees, and an interaction between the units on a tree was observed. This experiment has now been repeated, using whole trees as units, to amplify these results and to study seasonal influence.

The collaborative trial with the N.A.A.S. on the effect of various strengths of copper sulphate as a defoliating agent is showing encouraging results. The thinned trees have formed fruit bud in this, the ' on ' year, but the results cannot be fully judged until next season.

There were no differences in cropping between trees sprayed last year with different strengths of naphthalene acetamide (NAM) and unsprayed trees. Some trees which were sprayed with different strengths of DNC, however, and which carried no crop last year as a consequence, cropped more heavily than the unsprayed trees.

Similarly, trees in the trial of total deblossoming sprays which carried little or no crop as a result of the treatment, have carried a greater crop than control trees this year. There are no apparent unsatisfactory after-effects of the sprays, and it should be possible to use this method to change the phase of biennial trees in the orchard. The principal effect of the treatment is to remove all current growth at the time of spraying and to produce thereby a new flush of growth from dormant buds. The application of this technique to very young trees, or its repetition over consecutive years has yet to be examined.

Breeding

Rootstocks.—Mazzard rootstocks were crossed with several related *Prunus* species of dwarf habit with the object of producing new dwarfing cherry rootstocks. Poor germination of the seeds

is being overcome. The search for improved rootstocks for pears, involving crosses with the pear–quince hybrid, *Pyronia Veitchii luxemburgiana*, has been continued. Fruits and seeds have been obtained from crosses between this hybrid and the apple Cox's Orange. Crosses between the pear and the apple have again been made and the progeny of an earlier cross are being grown on with a view to their possible value as rootstocks.

Scion varieties.—Some ten thousand apple seedlings, mainly from crosses between Cox's Orange and late flowering varieties, were planted out and further crosses were made to yield another ten thousand. Selection among nine thousand seedlings raised during 1954 yielded 951 late leafing seedlings which have been planted out for fruiting. Of 87 late flowering apple varieties received from the National Fruit Trials, 41 blossomed later than Crawley Beauty in 1956.

Collaboration with the Entomology Section, to produce apple varieties of good fruit quality resistant to Woolly Aphid, has been continued. Crosses involving Northern Spy, Irish Peach, Court Pendu Plat and Cox's Orange have been made and are being subjected to infestation tests.

Much progress has been made in the selection of apple and pear seedlings, now in full fruit production, from crosses intended to produce new varieties of improved quality or extended season. Seven apple seedlings with very early maturing fruits have been overgrafted on to five-year-old frameworks of M.VII, and nine pear seedlings with fruits of good quality and appearance have been overworked on to six-year-old frames of Quince A and submitted for the National Fruit Trials.

Varieties

A progress report on the dessert apple variety trial that contains Beauty of Bath, Worcester Pearmain, Laxton's Superb, and the new varieties Harvest, Tydeman's Early Worcester and Tydeman's Late Orange has been prepared (see p. 81).

A field trial of Cox's Orange Pippin, using scions from trees having differing cropping and blossoming histories, has been planted. The trees are on rootstock No. 3436 and are being grown as spindle-bushes.

Most plums cropped heavily this year, but the fruit of many varieties was small. Twenty-one-year-old trees of Marjorie's Seedling gave an average crop of 670 lb. per tree. In the gage and plum variety trial, now 19 years old, Ontario gave over 300 lb. ; Warwickshire Drooper, Cambridge Gage, Denniston's Superb, and Comte d'Althann's Gage gave over 250 lb. ; and Victoria, Jefferson, Old Transparent, and Bryanston Gage gave 200 lb. per tree.

Small fruits

Variety and strain trials

Strawberries.—Replicated cropping trials, in which new heat-treated clones of Huxley, Perle de Prague, and Early Cambridge were compared with older clones containing mild viruses, were continued. As three-year plants, the heat-treated clones of both Huxley (M.403) and Perle de Prague (M.404) grew more vigorously and cropped more heavily than the old clones (M.44 and M.45), and the heat-treated clone of Huxley has now yielded more heavily for three seasons. In another trial heat-treated clones of Huxley and Early Cambridge (M.407) which had grown more vigorously and cropped more heavily in their maiden year than those of the corresponding old clone, continued to grow more vigorously in their second season ; but plants of the heat-treated clone of Early Cambridge carried many blind crowns. Blind crowns were also noted on several varieties which had not been heat treated ; thus it appears that the trouble is associated with seasonal conditions rather than heat treatment. Further investigation of this problem is in progress.

In the autumn of 1955 a new trial was planted to compare the heat-treated clones of Mme. Lefebvre (M.405), Cambridge Rearguard (M.409), Cambridge Prizewinner (M.412), and Early Cambridge (M.407) with old clones of these varieties carrying mild strains of virus. With the exception of Mme. Lefebvre which was damaged by frost, the heat-treated clone of each variety carried a somewhat heavier maiden crop than the old clone. With the increased leafiness of the heat-treated clones there was a tendency for the fruit to be more shaded and to ripen a little later than that on the old clones, a point that may be important with early varieties.

Botrytis rot was severe on all varieties in 1956, but Cambridge Regent was particularly badly affected. Talisman grew vigorously and gave a good maiden crop in a replicated trial. A few two-year plants of Talisman in a preliminary trial also cropped very well.

Comparison of two strains of Sovereign, S26 and S231, is being continued.

Plants of all the stocks of Auchincruive Climax selected from various sources have now shown transient yellows or streak. Only a few plants from the greenest families are now being retained. In a second trial of plants taken from green parents and from parents showing transient yellows and streak nearly every plant showed transient yellows and streak in the maiden year, but after three

years the plants from green parents were still decidedly more vigorous and carried a much heavier crop than those from affected parents. There was little difference between plants grown from early and late formed runners.

The results of some variety trials were published (E447).

Raspberries.—The disease survey made on raspberry canes during 1954–55 winter, was repeated in 1955–56 and showed a general increase in Spur Blight, but little change in *Botrytis* attack. Seedlings T and H showed marked resistance to Spur Blight over both seasons, as did their male parent, Lloyd George, while Seedlings Y and 51/47 were outstandingly susceptible, with Promise, Enterprise, Exploit, V, and Z of intermediate status. Lloyd George and Seedlings H and T showed the lowest percentage of canes attacked by *Botrytis*, whilst Promise, Norfolk Giant, Y, and V showed the highest. Detailed examination of fruit samples throughout the season showed some reduction in damage by Raspberry Beetle, compared with 1955, but varietal differences in disease and pest attack were obscured by severe gale damage at the end of July.

Yields of some of the varieties in the three cropping trials were good, Promise, Exploit, and Seedlings Z and T giving 4–5 tons per acre, although much of the crop of the later varieties was ruined by gales at the end of July. Yields of Norfolk Giant were further reduced by exceptionally heavy cane death during the winter.

Loganberries.—A field trial has been planted with five loganberry clones tested for freedom from viruses related to the decline of stocks of this crop. The foliage has been of good colour and size, and the plants have made ample cane growth.

Blackberries.—Preliminary observations on the Thornless Evergreen blackberry suggest that it is of medium vigour. The fruit, which is of good flavour, ripens rather late.

Propagation and maintenance of stocks

Strawberries.—Over 40 clones have been maintained as potted stock plants in insect-proof houses. Nineteen virus-free clones and six carrying mild viruses were propagated in gauzehouses, and runners from some of these plants have been sent to various other research stations in this country and abroad. Three isolated field runner beds were again maintained to meet our experimental requirements.

Loganberries.—In addition to the five clones already selected, plants of two promising strains of loganberry from the U.S.A. and one strain from Eire are being propagated by tip-layering for field trial. These clones are being concurrently tested for viruses by the Plant Pathology Section. In addition a clone of loganberry originally selected at East Malling in 1935 is being propagated and re-tested for viruses possibly related to the decline of planting stocks.

Blackberries.—A strain of Thornless Evergreen blackberry is being propagated by tip-layering. The clone is also being tested by the Plant Pathology Section for certain virus diseases.

Breeding

Raspberries.—Selfing down of parent lines has been concentrated on Seedling 30/8, Norfolk Giant, Burnetholm, and Lloyd George. Seedling 30/8, from a self of Pyne's Royal crossed with a self of Lloyd George, has now been inbred for three generations. It shows good vigour and is apparently homozygous for large fruit. Resistance to *Amphorophora rubi* is being transferred to this line from Baumforth A and from a derivative of Chief. Other characters being transferred to the 30/8 line include thornlessness and fruit quality. Selfing down of Norfolk Giant has been carried to the second generation ; germination of this material was very slow, but once the plants had become established their vigour was good. A large family grown from open-pollinated seed from an isolated area of Reid's Seedling (a self of Burnetholm) proved pure for thornlessness and contained many plants having good vigour. Selfing down of Lloyd George has only reached the first generation.

One very vigorous triploid seedling from Lloyd George × *Rubus palmatus* backcrossed to Lloyd George was retained, but the extreme thorniness and branching habit of all hybrids between *R. palmatus* and red raspberries makes it unlikely that anything of value will come from this cross.

Twenty-three seedling families were raised in 1956 and these included a number designed to elucidate the genetics of resistance to *A. rubi*, work on which was continued in collaboration with the Entomological Section. Surveys of resistance in *Rubus* species and in raspberry varieties were continued.

Currants and gooseberries.—Fertile hybrids of black currant × gooseberry were obtained as a result of colchicine treatment, and these were successfully back-crossed to gooseberry and also to tetraploid black currant (p. 73). In addition, crosses between black currants and red currants were grown with the object of backcrossing to Baldwin in order to increase the number of flowers per strig. Some of these hybrids were treated with colchicine. In the transference of the reduced spines of *Ribes oxyacanthoides*, from Hunter's breeding lines to English gooseberries, first backcrosses were made to English varieties.

Cytology.—A number of inter-species *Ribes* hybrids were made with a view to elucidating some aspects of cytological differentiation in the genus. In addition, chromosome counts were made on several *Rubus* species. The cytology of a sport of Laxton's Superb apple is being investigated.

Cultural measures

Strawberries.—The trial of different amounts of nitrogen, with and without irrigation, on Royal Sovereign, was continued in collaboration with the Fruit Nutrition Section.

A Growers' Bulletin on strawberry planting systems appears on p. 173. The modified matted row called the Hill-mat system appears to offer useful savings in planting and cultivation costs.

A weedkiller trial was begun on two-year Royal Sovereign plots. An application of sodium 2,4-dichlorophenoxyethyl sulphate (S.E.S. or Crag Herbicide), at 3 or 5 lb. per acre at monthly intervals before strawing and again when the plot had been mown and cultivated after fruiting, gave satisfactory control of fat hen, nettles, and groundsel without any reduction in crop or appreciable injury to the strawberries.

Studies are in progress on the effect of deblossoming on crown production, and the effect of burning or cutting after fruiting on leaf, root and crown growth, and on fruit bud differentiation.

Raspberries.—One acre of raspberries, half of Norfolk Giant and half of Malling Exploit, has been planted for future experiments.

Frost damage investigations

Many flower buds of peaches were killed by hard winter frosts, much reducing the crop of bush trees ; wall-trained trees, however, still carried a good crop. Some raspberry varieties also suffered damage in the winter due, it is thought, to desiccation of the tissues.

Following the grubbing of 33-year-old trees of Allington Pippin a study was made of frost rings in the trunk, caused by the severe winters 1939/40 and 1946/47.

Some spring frost damage occurred on 7th, 20th, and 30th April and on 21st May. Walnuts were severely damaged, and the yield of some black currants was reduced. Durondeau pears were badly damaged, but otherwise the crops of pears, apples, and plums were not seriously affected. In some cases the quality of the fruit was reduced by frost blemishes. Cherries cropped poorly but, in most cases, this was not due to frost damage.

A range of sprinklers, automatically controlled by a thermostat, was installed on the frost plot to protect apple blossoms from frost. An automatic device to wash out the pipes each time sprinkling began ensured that the filters did not become blocked by ice spicules from within the pipes. Although crops were not reduced, even in the unsprinkled areas, the protective effect of the sprinklers was evident from the absence of frost blemishes on sprinkled fruit. The comparison of fruit from sprinkled and unsprinkled areas also confirmed previous observations on the time of origin of this type of blemish.

In the laboratory, experiments were continued on the winter hardiness of two raspberry varieties, and of the spring-frost resistance of three cherry varieties at various stages of floral development. Fifty-five apple seedlings were tested for the relative frost resistance of their blossoms.

Experiments were continued on physiological factors associated with frost resistance of blossoms. Controlled temperature chambers, with artificial illumination, were used to give potted apple trees different degrees of hardening before blossom time. Before exposing the trees to freezing, samples of the flowers were taken for examination of their water relationships and sugar content. Similar samples of flowers were taken from orchard trees known to differ in their relative frost resistance.

Work was begun on the influence of mineral nutrition on frost resistance and physiological characteristics of fruit blossom, using Royal Sovereign strawberries and the apple variety Crawley Beauty, grown in sand culture.

A paper on the special frost research equipment appears on p. 93.

A paper was prepared for the 87th Annual Congress of the Société de Pomologie de France at Namur.

Mycorrhiza

Progress has been made with the problem of culturing the *Endogone* sp. responsible for mycorrhizal infection in fruit trees. It has been found that the percentage germination of resting spores can be greatly improved by selecting only spores of a particular appearance, by providing a period of cold treatment, and by germinating the spores in complete darkness. The growth of sterile germinated spores was markedly stimulated by placing them in agar near a dialysis bag containing non-sterile soil, sterile root extracts, or extracts of the green alga *Chlorella*. Similarly treated shoot extracts or extracts of dead roots had no stimulatory effect.

A preliminary examination was made of certain mineral constituents of apple cuttings with and

without mycorrhiza, grown in autoclaved soil in a greenhouse. The results suggest that mycorrhizal infection can affect the balance of nutrient uptake, although the principal differences were found in the composition of the roots rather than the leaves.

Walnuts

Owing to frost damage in spring, most walnuts carried only light crops.

Horticultural meteorology

Wind studies in orchards, with differently spaced trees, have continued and a report on this work is in the press.

The usual meteorological records have been continued at East Malling and at Throwley.

Publications During the Year

E436 Garner, R. J. (1955). **Double-working by double-shield budding.** *Grower*, 44, 810-3.

E437 Mosse, Barbara, and Scaramuzzi, F. (1956). **Observations on the nature and development of structural defects in the unions between pear and quince.** *J. hort. Sci.*, 31, 47-54.

E440 Preston, A. P. (1955). **Shaping and pruning systems for bush apples.** *Fruit Year Book 1956*, 42-6.

E441 Mosse, Barbara (1956). **Fructifications of an *Endogone* species causing endotrophic mycorrhiza in fruit plants.** *Ann. Bot., Lond.*, N.S. 20, 349-62.

E442 Preston, A. P. (1956). **Methods of pruning apple trees.** *Worcs. agric. Chron.*, 24, 104-9.

E443 ——— (1956). **Apple rootstocks.** *Worcs. agric. Chron.*, 24, 79-83.

E444 Modlibowska, Irena, and Rogers, W. S. (1955). **Freezing of plant tissues under the microscope.** *J. exp. Bot.*, 6, 384-91.

E445 Beakbane, A. Beryl, and Rogers, W. S. (1956). **The relative importance of stem and root in determining rootstock influence in apples.** *J. hort. Sci.*, 31, 99-110.

E447 Rogers, W. S. (1956). **The variety question in strawberries.** *Comm. Grower*, 1956, No. 3142, 345-9.

E448 Garner, R. J., Hatcher, E. S. J., and Kemp, R. W. (1956). **A comparison of black currant cuttings from stooled plants and fruiting bushes.** *Rep. E. Malling Res. Sta. for 1955*, 61-3.

E449 Trowell, G. F. (1956). **Weather conditions during 1955.** *Rep. E. Malling Res. Sta. for 1955*, 73-5.

E452 Preston, A. P. (1956). **Thinning apples by the leaf-count method.** *Rep. E. Malling Res. Sta. for 1955*, 157-8.

E453 Baldini, E., and Mosse, Barbara (1956). **Observations on the origin and development of sphaeroblasts in the apple.** *J. hort. Sci.*, 31, 156-62.

E455 Preston, A. P. (1956). **The control of fruit-tree behaviour by the use of rootstocks.** *Ann. appl. Biol.*, 44, 511-17.

E456 Beakbane, A. Beryl (1956). **Possible mechanisms of rootstock effect.** *Ann. appl. Biol.*, 44, 517-21.

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

Design and analysis

Many new experimental designs, 54 in all, were needed for the Research Station during the year ; in addition, for the N.A.A.S., seven were required for Experimental Horticulture Stations, four for the National Fruit Trials, Brogdale, and eight for other places. There is now practically no land at the Research Station, suitable for fruit, that has not carried fruit experiments already. After resting under arable crops for some years, several of these areas, limited in extent, became available for new experiments. Very careful planning was needed, taking into consideration the previous history of the land. Special problems included the fitting in of two or more neighbouring trials on limited areas and the design of areas of blackcurrants, raspberries, and pears for calibration as a prelude to new trials, details of which cannot be foreseen at the time of planting.

The number of analyses of data to be carried out rose sharply to 945, as compared with 683 in the year before and a usual figure of about 300 only five or six years ago. This number was swelled by assistance given to postgraduates preparing theses, so the figure may well fall again. Almost all data were dealt with by means of the analysis of variance or of covariance, or by correlation and regression methods, only ten sets of data needing other techniques. The chief use of covariance methods was with the provincial experiments of the N.A.A.S., most of which are on established trees.

A visit to the West African Cocoa Research Institute, Tafo, Gold Coast, provided an opportunity to study the particular difficulties of field experimentation with cocoa in that region, and recommendations for the design of some future experiments were made.

Analyses have been done and trials designed also for the Scottish Horticultural Research Institute.

Statistical research

Methods of experimental design and analysis

Work has continued on the problem of using plant material for further investigations after it has already been used in a previous experiment.

A method has been evolved, and will shortly be published, to make possible the valid use of parts of a tree, e.g. its branches, as the units of an experiment. Trials can now be designed in which the local effect of a treatment on the part receiving it can be separated from the remote effects of treatments applied elsewhere. Further, tests can be made to see if the local and remote effects operate independently of one another.

It sometimes happens that the effect of the control treatment requires to be determined with either more or less accuracy than that of other treatments. Several ways are already known of arranging for this economically, and more are being evolved.

A method has been worked out for the analysis of data expressed as the proportion of individuals in each of a number of grades.

Statistical studies in biology, including measurement problems

The past year has seen further collaboration with the Plant Physiology Section in studies of growth analysis. It is no new observation that there is variation even within clones, but the variation observed between the unworked rootstocks of these trials, which were grown in compost in pots, was such that further studies are needed to elucidate its source.

Revived interest has been taken in a method for studying sources of plant variation by noting changes in variability in a set of growing plants. This method was evolved some years ago at East Malling.

The grid for measuring leaf areas, described in the Annual Report for 1955, has been exhaustively tested throughout the growing season.

Historical studies

Much information has come to light concerning the history of Station land in the parishes of Ditton and Aylesford (see p. 49).

Field trials

The short-term phase of the trial on the restoration of land uniformity following a long period when the land was occupied by trees, has continued with the recording of the second year's growth

of the indicator plants (2 acres of Cox's Orange Pippin on M.VII) before grubbing and weighing them. A crop of mangolds was then sown which are to be recorded and the results compared with those of six years ago from the mangolds sown immediately after the trees had been grubbed. This completes the first phase of the trial, and the complete data are now being examined. The long-term phase was continued with the final year of arable crop rotation. This trial is carried out in collaboration with the Fruit Nutrition Section.

The detailed recording of the apple uniformity trial has continued, a newly-developed sampling method being used for the measurement of the 1955 extension growth and also for the 1954 growth on those trees on which the record had not been made in 1954–55. An unforeseen source of variation has been wind-rocking on two occasions.

Publications During the Year

M29 Pearce, S. C. (1955). **Experimentation with perennial crops.** *F.A.O. Publication.* InDEx/3,

M30 ——— (1956). **Studies in the measurement of apple trees. III. The use of branch girths as a substitute for the trunk girth.** *Rep. E. Malling Res. Sta. for 1955,* 76-9.

M31 Holland, D. A. (1956). **Soil acidity in relation to trunk girth of apples.** *Rep. E. Malling Res. Sta. for 1955,* 80-5.

M32 Freeman, G. H. (1956). **The selection and use of a panel for taste sensitivity tests with fruit.** *Rep. E. Malling Res. Sta. for 1955,* 86-8.

M33 Pearce, S. C. (1956). **Some problems of experimental design and technique for perennial crops.** *Biometrics,* **12,** 330-7.

M35 Hoblyn, T. N. (1956). **Some difficulties in the field experimentation with cocoa on the Gold Coast.** *World Crops,* **8,** 355-65.

M37 ——— (1955). **The Isaac Newton apple.** *The Observatory,* **75,** 134-5

III. PLANT PHYSIOLOGY

By H. W. B. BARLOW

Collaboration has continued between the Plant Physiology Section and the Research Institute of Plant Physiology under Professor F. G. Gregory, and the following report includes work of the latter's staff carried out at East Malling.

Studies of growth and form in fruit trees

Field experiments on the interaction of rootstock and scion

The large-scale experiment analysing the growth of composite trees of four rootstock varieties has made its final season's growth, and is to be 'harvested' in the winter 1956/57. During the year routine observations were made, and near the end of the growing season leaf samples were taken from which to estimate the total weight, area, and number of leaves on all the trees. A paper on the more immediate results of this experiment has been prepared.

Measurements have continued on the experiment on the effects of deblossoming, and of very heavy and very light pruning treatments, on the growth of four commercial scion varieties on M.IX and M.XVI. The complications of branch breakage mentioned last year were negligible compared with the damage done by the severe gale of 29th July ; several trees were broken off and many others were found leaning at various angles. The long-term effects of the root damage which must have resulted are impossible to predict. A closely-planted plot in this experiment was thinned, the 64 trees providing information on the relationship between growth as measured in this experiment in terms of shoot length, and the dry weight of the various parts of the tree.

An experiment last year on the growth of plum shoots and roots grafted on to heavily pruned nurse trees gave some very interesting results which have been written up for publication ; this year another experiment on these lines has been carried out with apple varieties of contrasting growth habit, with confirmatory results.

Some indications from mist- and water-culture experiments led to two field experiments ; one, concerned with the relative importance of initial stem surface and weight in subsequent growth, has not yet been evaluated ; the other, an investigation into the effect on growth of allowing one or more shoots to grow from the maiden stem, confirmed earlier findings in that total growth increases as more shoots are allowed to grow out, although the individual shoots may be smaller. A new indication is that the average increase in weight per gram of leaf is highest where only one shoot is allowed to remain.

Growth of young trees under particular conditions

The mist-culture system was not used this year as field commitments were too heavy, but it has been made ready for use next year, when it is hoped to investigate responses to root-pruning ; preliminary experiments of this kind were performed this year in water culture.

Small apple trees in solution culture this year did not do so well as last ; zinc toxicity is suspected. Though all data have not yet been collected, the low level of growth may have vitiated the results.

Growth in John Innes compost in pots, on the other hand, was satisfactory, and the relationship previously found between vigour and net assimilation rate was confirmed for a wide selection of unworked rootstocks when considering the whole season's growth ; over short periods this may not hold good.

Bud-break in these experiments was very variable this year, and this has complicated the interpretation of the results. A separate investigation of the length of the growing season was carried out. By suitable forcing or cold storage treatments M.II and M.XVI potted plants were made to break dormancy simultaneously, and at intervals from March until June (under natural conditions M.XVI is far later than M.II). In both varieties total growth appears to be directly related to length of growing season.

Work was resumed on the mobility of certain cations in the plant, in particular manganese ; techniques developed for the potato plant are being modified for use on the apple.

The method of measuring leaf area with the grid described in last year's Annual Report (p. 104) was compared with two other methods in extensive trials this year. The grid method was much the most rapid, and, for whole plants, as accurate as the others.

An apparatus for measuring the area of samples of detached leaves, which has been much in use this year, is described on p. 107 of this Report.

Growth of individual shoots

Last year's experiments, in which the response of the shoot to removal of leaves at various stages was investigated on stoolbed shoots of Crab C, indicated that leaf expansion, internode elongation, and lateral bud development, are all closely interwoven. An hypothesis relating these expressions of shoot behaviour, put forward in a paper delivered at a symposium on leaf growth in the spring, was tested in several experiments this year, both on Crab C and other rootstock varieties. In this, as in certain other studies this year, emphasis was laid on gaining a better understanding of the way in which leaves expand and lateral branches grow out ; the many field measurements taken will be supplemented by microscopical examination of material collected serially to show the early stages of growth of these organs and of the internodes.

Four main groups of experiments were carried out on these lines : (1) attempts were made with variable success to clarify the role of the shoot ' tip ' by subdividing what had been in previous experiments a rather arbitrarily-defined region, including leaves at various stages as well as meristematic stem tissue ; (2) growth responses were observed following the reduction of leaf area by removing various fractions of leaves rather than whole leaves, and by darkening whole leaves for a period ; (3) the potentialities of axillary buds at different stages of development were assessed by cutting shoots back to different levels ; (4) experiments to find out whether the effects of leaf removal showed up in the stem regions above that part directly affected, as should follow from the hypothesis mentioned above.

All these experiments suffered considerable damage by the gale of 29th July, and by a hail storm eight days later. As this damage often simulated some of the experimental treatments, many of the finer points it was hoped to settle were obscured.

Measurement of photosynthesis and respiration

The change in electrical conductivity of a highly dissociated base on neutralization has been used in the construction of apparatus for the quantitative determination of micro quantities of carbon dioxide. Even at the present stage of development the results have been most encouraging and it is now possible to measure either photosynthesis or respiration of a single immature apple leaf over a period of a few minutes. Apparatus for both field and laboratory use is being made.

Natural growth substances

The relation between natural growth promoters and inhibitors as defined by the coleoptile straight growth test, and the growth of the shoots from which they have been extracted, is by no means clear. Unfortunately work on the subject was brought to a standstill this year by two obscure technical difficulties. Firstly, chromatograms dried by our usual method suddenly exhibited (over the whole paper) a depressing effect on coleoptile extension ; the cause of this trouble has not been discovered, but it could be avoided by drying the chromatograms away from the laboratory buildings. Secondly, this practice itself led to our becoming aware that the synthetic growth promoter β-indolylacetic acid can rapidly disappear from chromatograms under a disturbing variety of storage conditions. This year either one difficulty or the other has been encountered, and sometimes both.

Meanwhile a bulk ether extract has been made of dormant Myrobalan B layer-bed shoots to obtain a concentrated solution of the main natural inhibitor for various biological and chemical tests. Twenty kilogrammes of fresh shoots were extracted, representing a total shoot length of about a quarter of a mile.

Vegetative propagation

An account of the development of controlled winter storage of cuttings and a description of the equipment appears on p. 101. This year the investigation, in collaboration with the Pomology Section, has been continued in two main experiments. In one, periods of high temperature (65° F.) were followed by storage at 45° F. until the cuttings were planted out at two dates in the spring ; it was clear that by stimulation of rooting by extra heat, cuttings may become vulnerable on planting out in open ground, and care must be exercised in applying ' forcing ' methods. In the second experiment cuttings were taken from four plum and three apple rootstocks on three occasions in the autumn, given two levels of growth substance treatment, and stored uniformly during the winter. Samples were collected at intervals from this experiment for an anatomical study of root initiation (see p. 10) which showed that roots arise as a result of meristematic activity *after* the cutting has been taken.

An outside trial on cutting length and depth of planting was conducted at Tonbridge School by boys of the sixth form.

A paper has been published on earlier collaborative experiments with the Booskoop Nursery

Research Station, Holland, and one appears in this Report (p. 60) on the effect of rootstock on the behaviour of scion cuttings.

Abscission

The experiment, in collaboration with the Pomology Section, on the effect of very early thinning of Sunset apples on the natural shedding of fruit and on the final crop has continued. Attempts to simplify the experimental procedure by various means were not altogether successful, but useful knowledge was gained to apply to next year's trial. Tree to tree variation in the effect of thinning was very great this year and only extreme treatments gave clear effects.

Fruit splitting in cherries and plums

Experiments on the effects of α-naphthylacetic acid (NAA) on fruit splitting were continued along two lines : (1) a closer study of the effect of concentration of the spray and of times of application to the susceptible cherry variety Bigarreau de Schrecken ; (2) additional pilot studies to gain experience with other susceptible cherry varieties, by courtesy of a commercial grower, and with susceptible gages available on the Research Station. Unfortunately this programme was bedevilled by the weather in two respects : firstly, rain repeatedly prevented or nullified application of spray at the intended times, and secondly, splitting in the untreated material was reduced to a very low level, possibly by prevailing low temperatures during the critical preharvest periods, especially for the earlier varieties studied. Difficulties were also experienced, both on the Research Station and elsewhere, in obtaining samples of fruit at the stage of ripeness required for this investigation.

This year's work has not produced any clear evidence of the value of NAA in reducing fruit splitting.

Spray damage

The study carried out last year on the response of M.II leaves to copper sulphate throughout the season (see p. 109 of this Report) was extended this year to include various scion varieties on different rootstocks, and at different sites on the Research Station. The most striking feature of the results was the absence of any effect of rootstock on the response of the scion, no matter how great the effect on scion size. As expected, the scions varied in their responses on a given occasion, but on different occasions they often responded very differently to the same concentration of copper sulphate, as had been found previously for M.II. Reasons for these changes in reaction during the season have not yet been found.

Publications During the Year

F80 Hatcher, E. S. J., de Boer, S., and Garner, R. J. (1955). **The influence of soil environment on the behaviour of apple and plum cuttings.** *J. hort. Sci.*, **30**, 268–81.

F83 Ruck, H. C., and Bolas, B. D. (1956). **Studies in the comparative physiology of apple rootstocks. I. The effect of nitrogen on the growth and assimilation of Malling apple rootstocks.** *Ann. Bot., Lond.*, N.S. **20**, 57–68.

F84 Gregory, F. G., and Hancock, C. R. (1955). **The rate of transport of natural auxin in woody shoots.** *Ann. Bot., Lond.*, N.S. **19**, 451–65.

F85 Barlow, H. W. B., and Hancock, C. R. (1956). **Internode growth in stoolbed shoots of the apple rootstock Crab C.** *Rep. E. Malling Res. Sta. for 1955*, 89–100.

F86 Bolas, B. D., and Ruck, H. C. (1956). **Experimental approach to the development of an adequate technique for water culture of apples.** *Rep. E. Malling Res. Sta. for 1955*, 101–3.

F87 Freeman, G. H., and Bolas, B. D. (1956). **A method for the rapid determination of leaf areas in the field.** *Rep. E. Malling Res. Sta. for 1955*, 104–7.

F88 Prasad, Ambika (1956). **Effect of nutritional conditions on the growth and chemical composition of 'source' plants and on the rooting of stem cuttings derived therefrom.** *Rep. E. Malling Res. Sta. for 1955*, 108–14.

IV. BIOCHEMISTRY

By A. E. FLOOD

Host-parasite relationships

Collaboration with the Plant Pathology Section in the study of host-parasite relationships has continued and has been developed along the lines indicated in previous reports. One such development has been the search for structural analogues based on natural metabolites of the host and known to be toxic to *Venturia* spp. The depside chlorogenic acid which is present in both apple and pear was chosen as a starting point. Tests in culture showed that its toxicity was due to the caffeic acid component, the quinic acid part of the molecule being inactive. A series of compounds showing structural modifications of caffeic acid were tested in culture against *Venturia* spp. when the following facts emerged. Of the compounds chosen, the —CH=CH·COOH group appeared to be necessary for toxicity, the effect of this grouping being modified by the position of hydroxyl groups in the benzene ring. Cinnamic acid, which is similar to caffeic acid except that it has no hydroxyl groups, was found to be most toxic and was unique in that it prevented germination of the inoculum.

Continuing the study of the effect of host polyphenols and amino acids on the growth of *Venturia* spp., the importance of qualitative variation in both groups of compounds has been noted and further work has shown the occurrence of synergistic effects among the polyphenols.

The significance of the polyphenol-amino acid ratio in the host has been reported previously. Work during the year on analytical methods has enabled a start to be made on a more critical examination of this ratio among apple and pear varieties showing varying degrees of resistance to *Venturia* spp.

Work has continued on methods of separation, identification, and quantitative determination of metabolites in fruit plants.

Rootstock-scion incompatibility

In connexion with incompatibility problems of pears on quince, three glycosides present in Quince A but apparently absent just above the union (Williams') have been examined and one identified as isoquercitrin. The other two appear to be rhamnoglucosides of quercetin and kaempferol.

Publications During the Year

K104 Cartwright, R. A., Roberts, E. A. H., Flood, A. E., and Williams, A. H. (1955). **The suspected presence of *p*-coumarylquinic acids in tea, apple and pear.** *Chem. and Ind.*, 1062–3.

C371 Kirkham, D. S., and Flood, A. E. (1956). **Inhibition of *Venturia* spp. by analogues of host metabolites.** *Nature, Lond.*, **178**, 422–3.

V. FRUIT NUTRITION

By D. W. P. GREENHAM

The object of the Fruit Nutrition Section is the study of fruit plants in relation to the supply and uptake of water and nutrients.

It is recognized that empirical information on the effects of orchard practices on fruit production has a certain value, but that the formulation of reliable applied advice appropriate to a wide range of orchard conditions depends on a sound understanding of the fundamental relationships involved in the nutrition of fruit plants. Such fundamental relationships concern the effects of variation in the root environment on the uptake of water and nutrients and on their distribution throughout the tree and their utilization in the physiological processes associated with every aspect of differentiation and growth, of which the ultimate and relevant expression is the quantity and quality of fruit.

In its first year, the Section has continued the trials in this general field of research which were already being carried on in the Pomology and original Biochemistry Sections. The approaches through field experimentation and through solution culture techniques are complementary. Most of the routine recording of growth and cropping in the field experiments is still carried out by the Pomology Section, while the Plant Analysis Section has determined the mineral composition of many samples of plant material.

Nutrient supply

Spray culture experiments on the effects of varying iron and magnesium supply

Continuing the series of experiments started in the original Biochemistry Section, the spray culture technique devised by Dr. Roach was again successfully used to grow M.VII apple rootstock layers in four levels each of iron and magnesium supply. As in previous years, detailed growth measurements were made throughout the season, and these should yield valuable information on the effects of nutrient supply on the gross physiology of the fruit plant. This season the chlorophyll content of plants grown in the iron series was also determined at intervals, for comparison with the corresponding data for iron content and net assimilation rate.

Determinations of the mineral composition of many samples from component parts of deficient and healthy plants grown in spray culture should enable relationships to be established between the uptake and distribution of nutrients and the growth activities of the plant.

Further work was carried out on the movement of magnesium within the plant, in relation both to growth and to the development of leaf symptoms of magnesium deficiency. For this investigation, the concentration of magnesium supplied to some of the rootstocks was changed midway through the season.

Following field observations that the apple varieties Lane's Prince Albert and Edward VII appeared to differ in their susceptibility to lime-induced chlorosis, these varieties were grafted on M.VII and M.IX rootstocks and grown in spray culture with high and low iron levels. No clear differences in susceptibility to chlorosis were apparent with this technique.

Field investigations

Long-term manurial trials.—In most cases, these trials also involve soil management treatments and their continuation provides an accumulating body of knowledge on the manurial requirements of fruit trees under various soil management systems. Attempts are made to relate the growth and cropping responses in these trials to the nutrient content of the leaves.

Cure of magnesium deficiency.—Interesting results are being obtained in trials started a few years ago. In a plantation of dwarf pyramid Edward VII on M.VII showing severe leaf scorching, the leaves remain healthy so long as trees are sprayed at fortnightly intervals with 2 per cent magnesium sulphate. Sprays of this concentration are also being used, with and without soil applications of magnesium sulphate, in experiments on magnesium-deficient stoolbeds of the apple rootstocks M.IV and MM.102. In 1956, foliar symptoms on these rootstocks were entirely prevented by the use of nine sprays and, unlike previous years, three sprays reduced the symptoms throughout the season. Leaf symptoms were also lessened after the third year of soil applications of magnesium sulphate. Growth measurements indicate an increase in girth of the rootstock shoots as a result of spraying with magnesium sulphate. As in 1954, mildew, *Podosphaera leucotricha*, was less prevalent on sprayed plots than on the unsprayed.

Water relationships

Effects of soil moisture supply on growth and cropping

Tree fruits.—The Laxton's Superb apple trees which are watered at soil moisture tensions of 0 cm. Hg and 20 cm. Hg have yielded nearly 4 bushels of fruit per tree whilst the trees watered at 0 cm. Hg tension, and the control trees, have yielded 3 bushels per tree. The wettest treatment has given 70 per cent, and the intermediate treatments 50 per cent, more fruit in the size grades $2\frac{1}{4}$–3 in. than the control trees. This result may seem surprising in view of the absence of any seriously limiting soil moisture deficits during the season but the improved crop from the irrigated trees is not the result of any one year's irrigation but the cumulative effect of 4 years' irrigation treatments on soil of low available moisture resources.

The trial on the Laxton's Fortune apple trees has, for the fourth consecutive year, shown similar but non-additive effects from irrigation and high nitrogen applications. Trees receiving low nitrogen without supplemental watering have cropped considerably below those trees which have either received high nitrogen alone or have received low or high nitrogen and have been watered when the mean soil moisture tension at 1 ft. depth has been 20 cm. Hg.

Small fruits.—The combined nitrogen manurial and irrigation experiment on strawberries has been continued jointly with the Pomology Section.

A new raspberry trial has been planted using as the experimental varieties Malling Exploit and Malling Jewel with Norfolk Giant as the guard variety. Treatments are clean cultivation with and without irrigation, and a complete straw mulch. In addition to determining the effect of different soil moisture conditions on the growth and yield of the experimental varieties, it is hoped to determine the extent that any differences in growth and yields between mulched and control canes are due to differences in soil moisture conditions.

Establishment of the raspberry plants has been satisfactory, but mulching in March delayed the development of new cane. Subsequent mulch applications will be in October and in future the mulching of newly-planted raspberries would be better delayed until after cane production.

Effects on the fruit tree of interrupting the conducting system

Continuing the trunk-cutting studies started the previous year on cordon pear trees, a further series of treatments was applied. No delay in blossoming was obtained, but reductions were shown in the length of extension shoots, in leaf size and in fruit size. Some of the trees were used for a study of the path of water movement in the region of the cuts by means of a dye injection technique.

Soil management studies

Evidence from the field trials is steadily accumulating on the practical value of orchard soil management systems involving swards and mulches compared with clean cultivation. The present state of knowledge has been outlined in recent publications. An understanding of the mechanism of the effects of soil management practices on fruit production depends on knowledge not only of the nutrition of fruit trees but also of the effects of soil management on soil conditions affecting the availability of water and nutrients to the roots. Some progress has been made in this direction, notably in relation to the effects of grass species (U3) and sward management (U2) on soil moisture conditions. This work, in conjunction with the investigations on effects of soil moisture supply on growth and cropping, is an example of the way in which elucidation of one of the factors has enabled recommendations on cultural practices (in this case the choice and management of orchard swards) to be made with greater confidence than was possible from empirical observations alone.

Some further observations have been made on the use of weedkillers to control the growth of couch grass around the base of fruit trees, and a short bulletin has been prepared (p. 184).

Collaboration with the Statistics Section has continued in investigations on the history of Research Station land (p. 49) and in the trial on the restoration of soil uniformity after grubbing a mature apple orchard (p. 16).

Publications During the Year

1 Greenham, D. W. P. (1956). **Orchard cover crops.** *Worcs. agric. Chron.*, **24**, 85–93.

2 Goode, J. E. (1956). **Soil moisture deficits developed under long and short grass.** *Rep. E. Malling Res. Sta. for 1955*, 64–8.

3 ——— (1956). **Soil moisture deficits under swards of different grass species in an orchard.** *Rep. E. Malling Res. Sta. for 1955*, 69–72.

4 Greenham, D. W. P. (1956). **Orchard soil management.** *Ann. appl. Biol.*, **44**, 521–5.

5 Goode, J. E. (1956). **Soil-moisture relationships in fruit plantations.** *Ann. appl. Biol.*, **44**, 525–30.

VI. PLANT ANALYSIS

By A. C. MASON

This Section was formed in October, 1955, to study changes in the mineral composition of the various tissues and parts of fruit plants with age and season, and to conduct research on sampling techniques in relation to the assessment of nutritional status.

The Section also has the task of carrying out analyses of plant material to meet the research needs of other Sections. In the past year several thousands of analyses have been carried out for a wide range of elements. Both spectrographic and microchemical methods have been employed. The investigations for which such analyses were made include : irrigation of apple trees and of strawberries ; long-term cover crop and soil management trials ; trials of magnesium sulphate and urea sprays ; long-term fertilizer trials with apples ; trial on the restoration of land uniformity ; spray culture nutrition experiment ; experiments on Nettlehead disease of hops ; and an apple storage experiment.

Studies on the mineral composition of fruit plants

The first results are available from an experiment on the mineral composition of Cox and Worcester apple trees on M.II rootstocks which are being grubbed at 3-year intervals over a period of 18 years.

The potassium concentration in the bark of all parts of the scion and stock and in the cortex of the roots was much greater where Cox was the scion. There was a similar difference for the wood of the last year's growth but not for the wood from older parts of the tree.

The concentrations of nitrogen and phosphorus in the bark of all parts of the scion were a little greater for Cox trees than for Worcester ; the same was true for the wood of the last year's growth and for the stele of the roots. The concentrations of these elements in other parts of the tree were not appreciably different for the two scions.

Analyses for calcium and magnesium yielded nothing of special note.

Apple rootstocks grown in pots and subjected to moist and dry soil treatments have been analysed. Details of the experiment and results are being prepared for publication.

The main conclusions from this experiment are that the concentrations of phosphorus, potassium, and calcium in the whole plant were increased by the moist treatment ; it was surprising to find that the concentration of nitrogen was decreased, a result which requires some qualification. The effects of treatment were not reflected equally well by the composition of all parts of the plant ; the highest correlation between composition of the plant part and composition of the whole was obtained, in general, with a sample of all the leaves, though mid-shoot leaves sampled early in July gave the highest correlation for nitrogen and potassium.

The total amounts of nitrogen, phosphorus, potassium, calcium and magnesium in all parts of the plant were greater in moist than in dry soil because the increase in dry weight was greater.

Studies in leaf sampling technique

Trees grown under different manurial and cultural conditions have been sampled in various ways to test the correlation of analyses of the various samples with tree performance. Such data will be collected over several years.

The minimum number of leaves required to form a representative sample from a mature Bramley apple tree has been studied. Eight leaves from the middle of new lateral shoots were adequate for the elements nitrogen, potassium and calcium, but 32 leaves were necessary when phosphorus was determined.

Analytical methods

A slide rule for the calculation of analytical results from spectrographic line densities has been designed for routine work.

The porous cup spark method is being examined for suitability for the routine determination of magnesium, calcium, manganese, and iron in plant material.

Work has proceeded on microchemical methods for determining iron, manganese and sulphur in plant material and the results are being prepared for publication.

VII. PLANT PATHOLOGY

By R. V. HARRIS

BACTERIAL DISEASES

Bacterial Canker of cherry (*Pseudomonas mors-prunorum*)

The comparison of the antibiotic streptomycin with the standard Bordeaux mixture against the leaf and canker phases of the disease was continued in field and glasshouse experiments.

The autumn inoculum-potential, measured as the number of leaf surface pathogens per gram dry weight of leaf, was slightly depressed by streptomycin, but very considerably depressed by 'low' strength Bordeaux mixture sprays applied in the autumn. Bordeaux mixture thus proved superior to streptomycin as a surface bactericide. Both sprays reduced canker infections, Bordeaux mixture being slightly better in this respect than streptomycin. Comparison of these results with the numbers of bacteria present on the leaves the previous autumn suggested that control with streptomycin might be greater than could be accounted for by its activity as a surface bactericide. The control with Bordeaux mixture was superior to any previously obtained with this bactericide, and this was attributed to the fact that sprays were applied much earlier in the autumn than had previously been the practice.

Excellent control of leaf spot was obtained with two blossom sprays of streptomycin applied in the spring but captan sprays applied at the same time were ineffective.

Experiments in the glasshouse with streptomycin on artificially infected cherry trees suggested that this antibiotic could penetrate into the leaf and prevent the development of bacteria already established inside.

Petri-dish tests established bacteriostatic action of streptomycin against *Ps. mors-prunorum* at below 1 part per million, and indicated a possibility that strains of the pathogen may differ in their sensitivity to this antibiotic.

Trees of the susceptible variety Napoleon were planted for a new field spraying trial designed primarily to compare streptomycin as a systemic bactericide with standard protectant copper sprays.

Bacterial Canker of plum

A continuation of the spray trial at the N.A.A.S. Horticultural Station at Luddington provided no advance on our knowledge of how to control the stem-canker phase, as distinct from the leaf-spot phase which is readily controlled by foliar sprays.

Cauliflower of strawberry

Work on this combined bacterium-eelworm disease, in collaboration with the Entomology Section, was largely concerned this year with experiments to test the ability of the bacterium, *Corynebacterium fascians*, to survive in field strawberries as a saprophyte (see p. 33).

FUNGUS DISEASES

Apple and Pear Scab studies

Stock clones of *Venturia inaequalis* were maintained under paraffin oil at 5° C. and were re-isolated from Cox leaves and the original wild types recovered. A new isolate of *V. pirina* was obtained from Williams' and its pathogenicity maintained by serial transfers on Williams' shoots. Nine clones of *V. inaequalis*, including three physiologic races, were received from Professor J. R. Shay of Purdue University and stored under oil.

Studies of the two pathogens in artificial culture, and related experiments on apple and pear trees under glass were continued in collaboration with the Biochemistry Section along the lines described in earlier reports. Advances in the former which are summarized in some detail in the Biochemistry Section report (p. 21) included two findings particularly demanding early *in vivo* investigation; first, the recognition of caffeic acid as the toxic component of chlorogenic acid, and second, of cinnamic acid as the most toxic of a series of analogues of caffeic acid when tested in culture against the two pathogens. This year's experiments under glass therefore largely consisted of tests of cinnamic acid as a scab inhibitor when applied either by injection into apple and pear shoots or as a foliar spray. These experiments yielded positive results of considerable interest, and in particular it may be noted that a formulation of cinnamic acid applied as a low-volume spray at 0·2 per cent caused no damage

to the shoots of either host, and considerably reduced the incidence of both diseases. It was active when sprayed either before or after inoculation, thus suggesting the operation of both protective and chemotherapeutic effects. The persistence of the cinnamate in leaves after injection was demonstrated chromatographically.

Verticillium Wilt of hops see also p. 192

Studies in host-parasite relations

A communication dealing with the earlier studies of toxic metabolites of *V. albo-atrum* in relation to the phenomena of Progressive and Fluctuating Wilt of hops and of varietal tolerance to the former was completed for publication. In view of the conclusion that such substances are probably not important in determining the degree of pathogenicity of the fungus or the tolerance of the variety, work on this aspect of the wilt problem was temporarily discontinued in favour of the studies of the internal resistance mechanisms referred to in last year's report. This year investigations were particularly directed to an elucidation of the phenomenon of tylosis. Tylosis accompanied by secondary wood proliferation as it occurs in Wilt-infected plants was induced quite independently of the disease, by small transverse cuts in the stem. It therefore appears that damage to the wood-conducting tissues gives rise to tyloses when the substances formed or released as a result of the damage are not immediately removed in the transpiration stream, and it is suggested that *Verticillium* metabolites act similarly as tylose-inducing substances.

Pathogenicity tests

Experimentation in our special tank equipment was limited this year to comparing the pathogenicity of isolates from four differing Progressive outbreaks. It is noteworthy, in view of the foregoing conclusions on tylosis, that some unidentified cultural condition in the pots this year caused extensive tylosis in the roots and stems of the test-plants, giving rise to a simulated ' tolerance '. None of the four ' progressive ' fungi showed any significant differences in pathogenicity under these somewhat abnormal conditions.

The Wye-East Malling breeding project

The intensive testing of the 2,000 seedlings in this project is now nearing its conclusion and this year three of the eight seedlings tested for tolerance proved comparable to OR55 in this character.

New ' interim ' wilt-tolerant seedlings under advanced trial

In continued observations on farm trials of D/1, D/3, J/2 and Whitbread's Golding Variety, Wilt-incidence was found to be generally low except on one farm where it reached 22 per cent in OR55, 25 per cent in D/3 and 17 per cent in J/2. Tests of the ' progressive ' fungus from the latter farm have so far failed to give evidence of any enhanced pathogenicity.

Verticillium-free stock of Whitbread's Golding Variety was made available to the Propagation Committee of the Hops Marketing Board who have allocated it to commercial specialist propagators. Similar stock of East Malling seedlings D/1 and D/3 was prepared and will be available for release, if the Research Station so decides, in the coming winter.

Verticillium Wilt of fruit plants

Pot plants of quince, plum and apple were infected with *V. dahliae* and *V. albo-atrum* and are in process of anatomical examination. Vascular obstruction in these hosts seems to be mainly by resins, though tyloses also have been found in plum. Vascular invasion apparently without any obstruction was observed in strawberry crowns infected with *V. dahliae.*

Ecological studies of pathogenic *Verticillium* spp.

The survival of V. albo-atrum.—Survival in hop residues in soils under various cropping and management programmes is being further investigated in a replicated field trial started this year.

Sporulation of V. albo-atrum.—Further direct observations confirmed that vigorous sporulation occurs on infected plant residues in soil and it seems that this is not markedly affected by soil treatments.

Antibiotics in controlling Progressive Wilt. –A fully replicated field trial to study the effect of griseofulvin was made ; no control of infection or of symptom expression was recorded. This experiment was, however, heavily loaded in favour of the pathogen.

Collar Rot of apple (*Phytophthora cactorum*)

The resistance of 29 clonal rootstocks towards 5 isolates of the pathogen was tested ; the results show marked variation both in rootstock resistance and in the pathogenicity of the isolates. A method for making such tests in the laboratory was developed and gave results approximating closely to those obtained from pot-tree inoculation. This method has greatly increased the scope and speed of such testing.

A start was made on testing soil and foliar fungicides against the disease ; the method of testing employed showed considerable promise and will shortly be used on a larger scale.

Results of the successful application of an apple-fruit isolation method for a study of the seasonal activity of the pathogen in the soil, and for comparing the infestations of a range of orchard soils, are showing that the pathogen is widely distributed in the soils of affected orchards and is not markedly concentrated around infected trees.

A study of the saprophytic existence of the pathogen in the soil has so far provided no evidence that any mycelial growth occurs in soil over a wide range of moisture-content.

Field observations of the progress of the disease in commercial orchards continued, and in one a field trial was set up to test the efficiencies of copper sulphate and copper oxychloride soil drenches in controlling collar infection.

VIRUS DISEASES

As forecast in the report for 1955 the Third Symposium on Virus Diseases of Fruit Trees in Europe took place at East Malling in early July when we had the benefit of discussing in the field our extensive collection of indexed material, and visiting selected outbreaks in local growers' orchards, with workers in this specialist field from ten other European countries. It was generally agreed that this meeting provided a valuable research occasion for the pooling and collation of visual-symptom data on the basis of an agreed range of indicator hosts, and that substantial advance had thus been made towards the compilation of a European key to the recognition of this complex group of diseases. This year we also had additional help on these tree-fruit diseases from a post-graduate student, Mr. D. J. Engelbrecht of South Africa, who was particularly associated with experiments on possible herbaceous hosts of apple mosaic virus.

In our research on strawberry virus diseases Dr. Norman Frazier of the University of California, an authority on strawberry virus diseases and insect vectors in U.S.A. and on the leaf-hopper vectors of diseases of the aster-yellows type, was primarily responsible with Dr. Posnette for the considerable advances made this year in research on the Green Petal disease and its insect vectors and on the aphid-borne decline diseases. These are briefly summarized in the report which follows, and are in course of preparation for full publication elsewhere.

Tree-fruit virus diseases

Apple.—A virus occurring in symptomless Lord Lambourne and M.IX and causing Green Mottle on peach was shown not to be rubbery wood virus. Starcrack virus disease seems to be more prevalent in orchards than was formerly supposed. A change in the growth habit of M.IV was found to be associated with Chat Fruit infection.

Pear.—The selection of new quince indicator clones has simplified indexing, and virus-tested clones of several varieties of pear selected by these improved indicators have shown better growth in the nursery than did the old infected clones.

Cherry.—Leaf Roll has been identified in eight Kentish orchards and the incidence of Rasp Leaf also has been found to be high.

A canker disease with similarities to Bacterial Canker was shown to be graft transmissible, and this disease is believed to be the cause of the prevalent spur canker on the variety Noble.

Plum.—Three apparently virus-free clones of Common Plum were selected. Transmissions from cherry to plum suggested that Rasp Leaf of cherry is associated with prune dwarf virus but further work is needed to establish whether the latter is part of a complex causing this disease.

Virus-tested sources of scion-varieties

Additional varieties of apple and cherry were made available to the Mother Tree Scheme this year and progress was made in the collection, virus testing, and propagation of further varieties.

Trees of seven varieties of pear were propagated from tested scion sources but some of these will require re-tests on our new quince indicators.

The propagation of mother trees of plum varieties has been delayed pending the availability of virus-tested rootstock clones.

Strawberry virus diseases

The identity of the aphid-transmitted viruses in England and California was established. The presence of a latent virus in the East Malling clone of *Fragaria vesca* was confirmed and a new clone is being selected ; the current classification of the aphid-transmitted diseases was re-examined in the light of this discovery.

Green Petal disease was transmitted by the leaf-hopper *Euscelis lineolatus* from strawberry to clover. Two viruses (or virus strains) occurring in clover and many other hosts were found to be involved in Green Petal disease.

Apple mosaic and plum line pattern viruses (probably strains of one virus) were transmitted to strawberry by grafting ; the symptoms induced resembled those of Strawberry Mosaic.

Further varieties were cured of virus infection by heat treatment and additional information on the limitations of this therapeutic method was obtained.

Strawberry Nuclear Stocks

Virus-tested runners of eight varieties were issued to the Nuclear Stock Association Ltd., the body responsible for ' intermediate multiplication ' under the Ministry's Special Stock Certification Scheme. Of these varieties, Talisman and Cambridge Prizewinner were first issues.

Nine varieties were propagated for similar issue in 1956/57, Merton Princess being included for the first time.

***Rubus* virus diseases**

The indexing of vigorous loganberry clones continued, and a nucleus of the Long Ashton culture of the original East Malling clone, known by test to be free from a virus found in certain subnormal stocks, was returned to Long Ashton for propagation and supply to the Nuclear Stock Association for possible development.

Studies of the virus or viruses present in subnormal loganberry clones included further graft-tests and a series of vector-tests ; the results of these are not yet available. Grafts were made to test the transmissibility of enation symptoms in a thornless variety.

A survey of loganberry plantations revealed three disorders which are being investigated. One of these, characterized by vein chlorosis and vein banding leaf symptoms, appears to be a virus disease, as the latter symptom was shown to be graft-transmissible to *Rubus henryi* and clonal loganberry.

Preliminary tests for virus were made on a vigorous clone of Bedford Giant, a Bedford Giant thornless sport and on an Evergreen blackberry from Oregon. Two abnormalities in Bedford Giant are being similarly studied.

Hop virus diseases

Nettlehead

The collation of a mass of records of the spread and distribution of Nettlehead in hop gardens has suggested that this virus is brought into gardens by a vector which acquires the virus from an alternative host plant. Investigations of the weeds found in and near hop gardens were therefore started ; these included the recording of the species of the weeds growing in hop gardens and of weeds with virus-like symptoms growing in the vicinity of gardens in which the disease was spreading. The latter were collected and graft-indexed to hop.

Mosaic

No insect transmissions of mosaic virus were obtained with vector tests of *Aphis fabae*, *Macrosiphum euphorbiae* or *Tetranychus urticae*. In a survey of hops for mites in gardens where mosaic is spreading, only *Tetranychus urticae* was found in large numbers.

Line Pattern

Attempts were made to transmit Line Pattern from hop to hop by grafting and by the aphids *Phorodon humuli* and *Macrosiphum euphorbiae*. Tests with the former were also made using Blaisdon plum showing Line Pattern as the infector and hop as the test plant.

FUNGICIDE INVESTIGATIONS

(See also under ' Bacterial Canker ' and ' Apple and Pear Scab studies ', above.)

Low-volume spraying against Apple Scab and Mildew

This work was developed along the lines described in previous reports (' Concentrate spraying ') first by an intensive experiment to determine the relations of droplet-size to Scab and Mildew control

and to spray damage. This experiment was made in collaboration with the National Institute of Agricultural Engineering, using lime-sulphur applied to small Cox trees by equipment specially designed by the Institute ; its results are not yet available.

On a larger scale, small-volume concentrate sprays of lime-sulphur with insecticides were compared with medium-volume medium-concentrate sprays on Cox and Worcester Pearmain.

We co-operated in continued N.A.A.S. extension trials with lime-sulphur in commercial orchards in the Cambridge and Canterbury areas ; N.I.A.E. prototype machines were again used, and this year insecticides were included. These trials will be fully reported elsewhere.

Low-volume spraying against Pear Scab

A spray trial on dwarf-pyramid pears was started this year to compare hydraulic with concentrate sprays of lime-sulphur and captan respectively.

Systemic fungicides against Apple Scab and Mildew

A field trial was started on a row of the susceptible M.III rootstock to investigate the systemic effectiveness under field conditions of the fungal antibiotic griseofulvin, and the known scab-inhibitor cinnamic acid (see p. 25) against these diseases. Natural Scab infection was aided in the usual way by dead-leaf inoculum, and lime-sulphur was used as the standard protectant fungicide control. Sprays were applied on one or more occasions and disease recording was designed as far as possible to distinguish surface-protectant from any systemic action of the fungicides. No consistent evidence of systemic control was obtained for either of the test fungicides, but in the case of Scab this may have been due to the very low general level of infection obtained under the prevalent weather conditions. It has not yet been possible to assess protectant action.

Apple-Scab spore-trapping

We co-operated with Dr. J. M. Hirst of Rothamsted Experimental Station in taking the spore-trap and weather records on a sub-station provided at East Malling. This is part of a regional trial designed to interpret local differences in primary Scab incidence on Bramley trees in terms of variation in the complex of spore-inoculum and predisposing weather factors.

Apple Mildew

Greenhouse infection studies.—These studies were continued in collaboration with Plant Protective Chemistry and the substantial progress made towards achieving a continuous and consistent source of mildewed shoots on the susceptible M.III rootstock, for fungicide screening, is summarized in the report of that Section (see p. 37).

Field studies.—A trial in collaboration with Plant Protective Chemistry to compare lime sulphur with an organic fungicide (DNOPC or karathane) against Apple Mildew, completed its third and final year, and the results will be reported elsewhere.

A more intensive trial, extending over several years on a row of M.III rootstocks, to determine the relative contributions of the standard early spring spray-applications of lime-sulphur to Mildew control, was concluded.

Apple storage rots by *Gloeosporium* spp.

The spray trial at Bassett's Farm, Horsmonden, was continued in this its second successive season by the kind permission and generous co-operation of Captain H. St.G. Ralling. Again we had the advantage of help on the spot by Mr. E. J. Guthrie of the Botany Department of the Imperial College of Science and Technology who combined superintendence of this trial with his studies, under Professor P. H. Gregory, of the sources and natural transport of *Gloeosporium* spore inoculum in the orchards of the farm. In this year's trial the replicated spray-treatments on the plots were re-allocated to enable cumulative and individual seasonal effects to be determined severally. The full results of the 1955 spraying became available this year and showed that a captan spray applied in July, August and September respectively had reduced fruit infection and that the best results had been obtained when all three monthly applications were made. In that year a September spray alone, however, gave a degree of control which was not improved by an additional spraying in August. The results of the 1956 spraying are not yet available.

Silver-leaf of plums

The detailed study, started in 1952, of the invasion of the stems of young plum trees artificially inoculated with *Stereum purpureum* has for its objective the investigation of the possibilities of aiding

natural recovery by the injection of fungicides into the ' occupied zone '. The selection of a standard inoculation technique for testing the fungicide injectants was completed, and experiments were started to assess any effects of this injection technique itself (wounding, etc.) as distinct from those due to chemotherapeutant action of the fungicide.

Strawberry Botrytis Rot

Small *ad hoc* screening tests on picked fruit under glass were made by the method previously devised and now published. Cinnamic acid (see p. 25) showed some protective action, but the fungal antibiotic griseofulvin was ineffective under these test conditions. Cinnamic acid was less effective than thiram, a fungicide which had shown marked promise in previous tests.

The joint extension trial at the N.A.A.S. Experimental Horticulture Station, Luddington, referred to in last year's report, was continued for a second successive season and will be fully reported elsewhere.

Publications During the Year

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C362 Harris, R. V., and Posnette, A. F. (1956). **The production and distribution of virus-free fruit trees.** *Rep. E. Malling Res. Sta. for 1955*, 115-9.

C363 Posnette, A. F. (1956). **Strawberry Mosaic virus disease.** *Rep. E. Malling Res. Sta. for 1955*, 120.

C364 Crosse, J. E. (1956). **An epidemic leaf spot and spur wilt of cherry caused by *Pseudomonas mors-prunorum*.** *Rep. E. Malling Res. Sta. for 1955*, 121-5.

C365 Talboys, P. W., and Wilson, J. F. (1956). **A study of wilt-tolerance in the hop by means of intervarietal graft complexes.** *Rep. E. Malling Res. Sta. for 1955*, 126-30.

C366 Posnette, A. F., and Hoblyn, T. N. (1956). **Virus-tested rootstocks and scion varieties available at East Malling Research Station.** *Rep. E. Malling Res. Sta. for 1955*, 151-2.

C367 Crosse, J. E. (1956). **Bacterial Canker of stone-fruits. II. Leaf scar infection of cherry.** *J. hort. Sci.*, **31**, 202-24.

C368 Frazier, N. W., and Posnette, A. F. (1956). **Leafhopper transmission of a clover virus causing green petal disease in strawberry.** *Nature, Lond.*, **177**, 1040.

C370 Kirkham, D. S. (1956). **A culture technique for *Venturia* spp. and a turbidimetric method for the estimation of comparative sporulation.** *Nature, Lond.*, **178**, 550–1.

C371 ———, and Flood, A. E. (1956). **Inhibition of *Venturia* spp. by analogues of host metabolites.** *Nature, Lond.*, **178**, 422–3.

C374 Posnette, A. F. (1956). **The leaf roll virus disease of sweet cherry.** *T. Pl. zickten*, **62**, 49–50.

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VIII. ENTOMOLOGY

By A. M. MASSEE

Tree fruits

Woolly Aphid : resistant apple seedlings

Seedlings of Cox's Orange Pippin × Northern Spy parentage, found to be resistant last year, maintained their resistance this year after repeated inoculations throughout the spring and summer. Of 111 seedlings of the parentage Court Pendu Plat × Northern Spy tested for the first time, 22 proved resistant. Three plants proved resistant out of the 109 Crawley Beauty × Northern Spy plants which received their initial test. One hundred and twenty-two seedlings of Crawley Beauty × Court Pendu Plat all proved susceptible.

Two apple stocks Nos. 90 and 411 tested originally in 1951 and 1952 and found to be resistant, were both tested again this summer, and the immunity exhibited in former years was maintained.

Two Northern Spy stocks inoculated in May, each supported a small colony of aphids. These colonies thrived for a period of two months and immature aphids were noted. Galls were not formed on the affected shoots.

The nature of resistance is being studied in collaboration with the Pomology Section.

Apple Blossom Weevil

Routine inspection of selected plots has shown no evidence of reinfestation.

Pear Psylla

Studies of the biology of the Pear Psylla, *Psylla pyricola* Föer. have been concluded. It has been established that only one species occurs on pear in this country. There are three generations each year, and the insect overwinters in the adult state. A report on this work appears on p. 135.

Ecological studies

The trial to assess the effects of fungicides on the orchard fauna at Stondon Massey, Essex, in collaboration with the Plant Protective Chemistry Section, has ended. Lime-sulphur applications resulted in higher populations of Fruit Tree Red Spider Mite than captan ; both were used with a minimal insecticide programme. After four years, Fruit Tree Red Spider Mite populations developed from a very low level to produce conspicuous bronzing on lime-sulphur sprayed trees, while a constant low level was maintained with captan. Records of the insect predators have been taken throughout.

At the Essex Institute of Agriculture, Writtle, the Worcester plot previously used for a summer ovicide trial has received two chlorfenson applications, in order to iron out the differences caused by the earlier treatments. Both the Fruit Tree Red Spider Mite and the Black-kneed Capsid (*Blepharidopterus angulatus* (Fall.), are now at a very low level.

Insectary studies of the influence of *Typhlodromus tiliae* Oudms. and the Fruit Tree Red Spider Mite on each other have continued, comparing different relative densities and actual densities of the two species. The effectiveness of *T. tiliae* in checking red spider mite populations under these conditions has been compared with that of *Typhlodromus findlandicus* (Oudms.) ; *T. tiliarum* Oudms. and *Phytoseius macropilis* (Banks).

Records of beneficial insects and mites, and of phytophagus mites, have been compiled for a number of years in a neglected orchard. This year one half of the orchard has been cleared of undergrowth to determine the effect of the ground flora on the fauna of the apple trees.

The study of the integrated action of insecticides and fungicides on the Fruit Tree Red Spider Mite and its predators in collaboration with Plant Pathology and Plant Protective Chemistry Sections, is in its fourth year. Field observations indicated that the predator, *Blepharidopterus angulatus* (Fall.) was responsible for the reduction of the mite to a very low density on both plots available for this study. In the absence of the mite, the predator was observed to feed readily on all stages of leaf hoppers which also were numerous on the trees, and provided sufficient food to maintain the predator population.

The mark, release, and recapture technique was used to compare the survival rate of a dense population of *B. angulatus* with that of a less dense population, both populations occurring on the same field. The mortality of the larval stages of these two populations was investigated by means of a beating technique. Development rates and fertility rates of *Psallus ambiguus* (Fall.) and *Anthocoris nemorum* (L.) were under observation in constant temperature rooms.

Some success was achieved in making mite brushing machine records more permanent by brushing the mites on to cardboard discs printed with a counting grid and coated with a clear paper varnish. The varnish satisfactorily preserved the mites for counting at a later date.

Biology of Aphids

Studies of species infesting apple, pear, currant and gooseberry are now almost complete. Work has started on the *Prunus* aphids.

Concentrate spraying as a means of pest control

Small-scale field trials have shown that the Apple Sawfly (*Hoplocampa testudinea* Klug) can be effectively controlled with an insecticide applied at three or more gallons per acre, depending on the size of the tree. The work is developing in collaboration with the Plant Protective Chemistry Section.

Spring washes

The results of trials to evaluate the efficiency of DDT and BHC against Apple Sucker (*Psylla mali* Schmid.) and Winter Moth (*Operophtera brumata* L.) caterpillars have shown that further work is required to study the effect of both concentration and time of application. This investigation is being made in collaboration with the Plant Protective Chemistry Section.

Study of Codling Moth and Tortricid moths of the orchard

A preliminary spraying trial has been carried out in collaboration with the Plant Protective Chemistry Section in order to compare the values of ryania, lead arsenate, and two formulations of DDT for the control of Codling Moth. The effects of these sprays on the leaf hopper and Fruit Tree Red Spider Mite populations were recorded.

The mercury vapour light trap has again been used throughout the season to record the flight periods of Tortricid moths, particularly Codling Moth and the Summer Fruit Tortricid. The emergence period of Codling Moths and of the parasites of their larvae have been observed. The structure of the larvae of various species of *Tortricidae* is being studied to find characters of diagnostic value.

Leafhoppers

A general survey of the leafhoppers associated with fruit has been initiated, and the life-histories of the three most important species that occur on apple, namely, *Erythroneura alneti* Dahlb., *Typhlocyba froggatti* Baker, and *T. rosae* L., have been studied in detail.

Studies are in progress on the species of the genus *Macropsis* which occur on *Rubus*. Work on the biology and control is being carried out in collaboration with the Plant Pathology Section.

Small fruits

Strawberry Aphid investigations

The rate of spread of the apterae of the Strawberry Aphid (*Pentatrichopus fragaefolii* Cock.) in field plots has been studied.

Control of *Ribes* aphids

Earlier results have been confirmed that control of aphids on currants and gooseberries can be obtained with spring washes, although timing may be an important factor.

Raspberry aphid : testing *Rubus* species

Families of seedlings of selected parentage and potted material of various *Rubus* spp. have been tested in the insectary for resistance to *Amphorophora rubi* (Kalt.). Field counts have been made on the families tested and planted in 1955. The susceptibility of *Rubus* spp. to *A. rubi* collected from different sources has been studied. Field counts are being made on a number of different raspberry varieties to establish leaf preference, breeding behaviour, population fluctuations and varietal preference of *A. rubi*. These investigations are being made in collaboration with the Pomology Section.

Blackcurrant Gall Mite

The life history of the Blackcurrant Gall Mite (*Phytoptus ribis* Nal.) during the dispersal period is being studied and preliminary screening tests have been carried out on selected acaricides in search for more effective control measures.

Strawberry Seed Beetle and allied species

Trapping of the Strawberry Seed Beetle (*Harpalus rufipes* (Deg.)) and other Ground Beetles in strawberry beds has continued. The life-cycle of *H. rufipes* has been worked out in detail, and studies of the biology and ecology of this and other species continue. Experiments with dieldrin, in collaboration with the Plant Protective Chemistry Section, confirmed that the residues on strawberries were at an undesirably high level. An attempt to prevent damage by excluding beetles from strawberry beds by the provision of a trap trench with sprayed straw in its base, failed to provide effective control.

Nematodes

Soil migratory nematodes

Nematodes of the above multigeneric group have been reported as causing root damage, leading to decline, root rot or replanting problems on many crops and in many parts of the world. Attention is being concentrated on three otherwise unexplained problems which occur locally in Kent, namely (1) a slow decline of apple ; (2) a replanting problem in cherry ; and (3) poor root development and decline of strawberry.

Soil and root sampling has shown that nematodes of some or all the following three genera are numerous at each site.

(*a*) Root Lesion Nematodes (*Pratylenchus* spp.), which invade and multiply in the cortex of roots and have been recovered in large numbers from all three host plants.

(*b*) Stylet Nematodes (*Tylenchorhynchus* spp.), which feed on plant roots but rarely enter them, and can maintain themselves on potted apple and cherry plants.

(*c*) Pin Nematodes (*Paratylenchus* spp.), which feed as do Stylet Nematodes but seem less well adapted to apple and cherry.

Etiological investigations are in progress to determine whether any or all of these nematodes are responsible for the poor plant performance in the field. It is difficult to distinguish clearly between injuries caused by nematodes and those caused by other soil-inhabiting organisms ; due allowance must also be made for the possibility that root injury caused by nematodes may initiate complex interactions involving pathogenic fungi and bacteria. A marked increase in vigour and root health can be obtained in apple, cherry, and strawberry by freeing the soil from nematodes with fumigants or gentle heat. However, it is at present impossible to say how much of this improvement is due to nematode control and how much to other changes brought about by the treatments applied to the soil. Attention is therefore being directed to the development of new techniques for the establishment of large monospecific cultures of the more numerous plant parasitic nematodes so that their effects may be assessed individually.

Leaf and stem nematodes (*Aphelenchoides* spp. and *Ditylenchus dipsaci*)

Field experiments on the control of this group of strawberry-attacking nematodes with organophosphorus insecticides (chiefly parathion) have now been concluded. Some practical preventive measures have been developed but no safe and economic nematicide has been revealed by these trials.

In collaboration with Plant Pathology Section a further trial has been begun to determine the effective life under field conditions, but in the absence of nematodes (*Aphelenchoides* spp.), of strawberry ' cauliflower ' strains of *Corynebacterium fascians* (Tilford) Dowson. Pure culture etiological studies on these two organisms are at present in abeyance, but a joint paper on past work is in preparation.

Study of gall mites and predacious mites

Phytoptid mite material has been received from various sources and has been determined. A number of species of predacious mites have been studied, and a paper on this work is being published.

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D293 Pitcher, R. S. (1955). **The larval instars of some gall midges of the genus *Thomasiniana*.** *Proc. R. ent. Soc.*, London, **30**, 97–102.

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D296 Massee, A. M. (1956). **Notes on some interesting insects observed in 1955.** *Rep. E. Malling Res. Sta. for 1955*, 131–4.

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D300 COLLYER, ELSIE (1956). **Some predacious insects of fruit trees : lacewings, ladybirds and hover flies.** *Rep. E. Malling Res. Sta. for 1955*, 155–6.

IX. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

Insecticides

Chemical analysis

Further work has been carried out on methods of analysis, especially of residues.

DDT.—The modification in the Schechter-Haller method has continued to give satisfactory results. Extracting the diluted acid digest with benzene while it is still warm has been shown to be preferable to extraction with carbon tetrachloride, and sodium methylate is preferred to alcoholic potash for colour development.

gamma-BHC.—The Schechter-Hornstein method, essentially as modified by Martin and Batt, is regarded as superior to the non-specific method of Phillips, based on the oxidation of a *gamma*-BHC-aniline condensate.

Chlorbenside.—As this acaricide may be present on the plant as the sulphide, the sulphoxide or the sulphone, the latter two were prepared and a method, based on that of Higgons and Kilbey for chlorbenside and on that of Martin and Batt for chlorbenside in the presence of DDT or BHC, has been worked out for the determination of microgram quantities of any one of the three in mixtures.

Chlorbenzilate.—This has been determined by the method of Harris, but benzene was again preferred for the extraction stage.

Aldrin and dieldrin.—The phenyl azide method of O'Donnell *et al.* has been used ; this reagent appears to be sensitive to light so that high blanks were common and results not readily reproducible.

Total chlorine.—Semi-micro determination of total chlorine present in organic combination has been made by turbidimetric measurement of the silver chloride formed by the action of sodium and *iso*propanol. This method is non-specific but has been calibrated for DDT, *gamma*-BHC, aldrin, dieldrin, and the chlorine-containing fungicide, captan, and found to be a useful guide when other sources of chlorine are negligible or absent.

Organomercurials.—Collaborative work on analysis of compounded products continued, and it now seems that the mercury content can be estimated of any product at present offered to the grower.

Laboratory study of deposits.—In order to study deposits on various surfaces, an apparatus has been constructed in which sprays can be applied from an artists' spray pencil to slides or plants revolving on a simple turn-table. The half-life of *gamma*-BHC deposits on glass has been shown to decrease by about two hours for every degree rise in the temperature at which the slides were stored ; similar studies with other insecticides are in hand.

Pre-blossom sprays

Several pests of economic importance on apple are controlled by pre-blossom sprays, and the timing of these sprays is important. DDT has proved of special value against caterpillars and capsids, BHC against aphids and sucker. In an attempt to reduce the amounts of these chemicals required for effective control, Long Ashton workers evolved a mixture with benzene as solvent and di-octyl sodium sulphosuccinate as surface active agent. A trial was conducted, with the Entomology Section, in which three treatments were applied at mouse-ear versus full green-cluster. These treatments were 0·025 per cent DDT plus 0·007 per cent *gamma*-BHC ; 0·025 per cent DDT ; and 0·007 per cent *gamma*-BHC, all formulated according to the Long Ashton recommendation. The results suggest that the insecticide levels used, especially that of DDT, may be too low for reliable control, and further work is contemplated.

Apple Sawfly control by low-volume sprays

A third year's study was made, in collaboration with the Entomology Section, of several insecticides applied at low rates in small volumes by suitable apparatus as compared with applications by normal hydraulic spraying. Aldrin, *gamma*-BHC, or endrin, suspended either in water or in neat lime-sulphur, provided as good control as was obtained from the same dosage of these materials applied in normal concentrations at 250 gal. per acre.

Studies were also continued on the stability of *gamma*-BHC, DDT, aldrin and dieldrin when mixed as emulsions with lime-sulphur. Only *gamma*-BHC showed decomposition and this amounted only to about 6 per cent even when neat lime-sulphur was used ; lower concentrations of the fungicide produced no loss of insecticide. It seems justifiable to conclude that emulsifiable formulations of these insecticides may safely be used with any concentration of lime-sulphur for combined control of Apple Sawfly and fungal diseases.

Codling Moth control

Results of trials in 1953 and 1954 are included in a paper in Part III of this Report (p. 152).

In collaboration with the Entomology Section, a preliminary trial was carried out to assess the value of the relatively new insecticide, ryania (powdered stems of *Ryania speciosa*), as compared with lead arsenate and DDT. Ryania appears to be intermediate in effect against Codling Moth and certain other orchard insects.

Strawberry ground-beetle

On strawberries sprayed to control ground-beetles, further analyses of dieldrin residues, both by the non-specific total chlorine and the phenyl azide methods, confirm 1955 results. Levels ranging from 8–10 p.p.m., on fruits sprayed just before harvesting, to 0·5 p.p.m. on fruits harvested from plants sprayed five weeks earlier, show that it would be very difficult to avoid unacceptable residues at harvest, and the conclusion is that fruiting plants should not be sprayed with this insecticide.

Deposition and persistence of insecticides

The level of DDT present at the blossom period has been shown to depend mainly on the amount of foliage present when the insecticide is applied ; thus approximately ten times as much DDT remains from applications at full green-cluster as from spraying at mouse-ear.

Very similar initial deposits of DDT were obtained from a wettable powder and from an emulsifiable concentrate applied at 0·1 per cent DDT in the third week of June, but the persistence of the DDT in the emulsion was much greater. This is reflected in the amounts recovered after 3 weeks, namely, 30 p.p.m. from leaves sprayed with the wettable powder and 220 p.p.m. from emulsion-sprayed leaves; of these deposits 75 per cent could not be recovered with cold methanol and must therefore be regarded as no longer on the surface. Higher levels were deposited on leaves of Cox's Orange Pippin than of Worcester Pearmain.

In August, when leaf-growth was virtually complete, emulsions containing DDT, *gamma*-BHC, chlorbenside or chlorbenzilate were applied at various levels ; it was found that the initial deposits were directly proportional to the concentrations applied. Half the *gamma*-BHC deposit had disappeared within a day ; the persistence of *gamma*-BHC, chlorbenside, chlorbenzilate, and DDT increased in that order in the ratio 1 : 3 : 6 : 12. When applied as a wettable powder, *gamma*-BHC had much the same persistence as the emulsifiable form ; presumably this insecticide is lost mainly by volatilization and comparatively little enters the leaf even from an emulsion. Five weeks after these applications, no DDT could be recovered from leaves by cold methanol, although the total DDT present was 250 p.p.m. on leaves sprayed with 0·2 per cent DDT ; this again emphasizes that persistent DDT is not on the surface, and that selective action may in consequence be expected.

Biological assessment of deposits

Further work has been done on methods for rearing orchard insects and mites ; this has been facilitated by the provision of a glazed laboratory. Studies on storage of plant material, bearing eggs or for use as food, have continued in collaboration with Ditton Laboratory.

Preliminary work with material obtained from Entomology trials involving insecticides led to the establishment of laboratory techniques for studying spray deposits on orchard material. These techniques were used to study the toxicity to various insects of insecticide deposits from the Codling Moth trial referred to above, in parallel with the chemical analyses. In general the biological effects were closely correlated with the chemical present.

Fungicides

Glass-slide tests

Further tests, using spores of *Venturia inaequalis* and *Botrytis cinerea*, were carried out on a series of oxidation products of nabam. These indicated that products which were much less water-soluble but of considerable toxicity, especially towards *V. inaequalis* spores, could be obtained, but that none of them were superior, in this type of test, to captan (see p. 146).

Two analogues of captan were prepared, one from phthalimide and one from succinimide. The phthalimide analogue proved fully the equal of pure captan in the slide test against *V. inaequalis* and *B. cinerea* ; the other was slightly inferior.

The interaction of oxine and wetting agents was further studied in slide tests, but with inconclusive results.

Apple Mildew

Progress was made in the development of a greenhouse technique for rearing potted apple rootstocks and infecting them with powdery mildew. A major difficulty lies in the nature of the spores which prevents assessment of the spore load applied. However, by using several shoots to provide spores for each test, good infection was obtained late in the season. It was also found that watering the plants with a solution of ammonium nitrate increased the susceptibility of leaves. Artificial illumination to maintain day-length kept plants growing much better than those left in the open as the season wore on, but the leaves were less susceptible to mildew attack. Although lesions were most numerous on the fourth unrolled leaf, still younger leaves were shown to be even more susceptible when lesions were rated on unit area. A test to compare cinnamic acid at 0·1 per cent with lime-sulphur at 1 per cent showed clearly that the former offered little promise of control.

A third year has been completed in the trial on dwarf pyramids where lime-sulphur has been compared with DNOPC, as a wettable powder, with or without captan at half the usual strength. The overwintering mildew is now negligible on all treatments and scab has been satisfactorily controlled where captan was added.

Effects on mites and insects

The trial on Cox's Orange Pippin at Stondon Massey, Essex, was continued for a fifth and final year ; DNOPC was applied as a wettable powder in place of the mixed lime-sulphur/captan programme used as one treatment in the previous three years.

Phytotoxicity

Studies have been made on the passage into the shoot of copper, from leaves dipped in copper sulphate solutions, but only small replication is possible and errors are large. A good deal of the season's effort has gone into attempts to refine the method. Over the range, 2–45° C., temperature seems to have very little influence on the rate at which copper enters detached leaves, at least with low concentrations of copper sulphate ; at higher concentrations, the temperature effect becomes more noticeable, especially between 20 and 45° C.

The trials on small trees on M.VII with various chemicals have continued, and also on pear, plum and soft fruit plots. Severe loss of crop was again recorded where PMC was used on Conference pears ; a trial comparing several organo-mercurials with a sulphur programme on three pear varieties has been started. PMC at a concentration of 0·005 per cent caused no defoliation or crop damage for the third successive season on Tydeman's Late Orange, Tydeman's Early Worcester, Sunset, Fortune, Michaelmas Red and other new varieties. No adverse effect was seen on Lane's Prince Albert sprayed with captan or DNOPC or both. The trials with a number of chlorinated phenyl benzenesulphonates, including fenson (CPBS) and chlorfenson (CPCBS) have continued.

Urea, with or without the impurity, biuret, was applied three times post-blossom to 4-year-old trees of Cox's Orange Pippin, Worcester Pearmain and Laxton's Superb ; no damage was seen, and in September trees which had received urea looked greener than the controls.

Early Laxton and Victoria plums showed no damage from sprays of chlorfenson or chlorbenside, applied in May or June.

Frost damage reduced crops on Wellington XXX and Boskoop Giant blackcurrant bushes, but no additional losses were recorded on bushes sprayed with 2 per cent lime-sulphur at high volume or with neat lime-sulphur at low-volume, at the grape-stage.

Publications During the Year

Q88 Tew, R. P., and Groves, Joan R. (1956). **Some field experiments upon the control of Codling Moth, *Ernarmonia pomonella* (L.) by organic insecticides.** *Rep. E. Malling Res. Sta. for* 1955, 146–8.

Q89 ———, and Gambrill, R. G. (1956). **The Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch) : a further pilot trial in the field of two ovicides applied to apples at pink bud.** *Rep. E. Malling Res. Sta. for 1955,* 149–50.

X. SCIENTIFIC LIAISON

By H. B. S. MONTGOMERY

The research in progress on the problems of growing fruit continued to be made widely available by letter and telephone to enquirers at home and overseas. In addition, almost 2,000 visitors were received and shown various aspects of the work in the experimental plantations and in the laboratories ; of these some 250 came from overseas.

Five Members' Days were held with a total attendance of 850. The subjects were the Malling-Merton rootstocks, the storage behaviour of Cox's Orange Pippin, the rooting of cuttings, hop diseases, and soil management.

Rehearsals for these Members' Days provided opportunities for the officers of the official advisory services to keep up to date with the station. In addition, the usual two-day visit of the N.A.A.S. and the courses for hop and rootstock certification were held. The total attendance on these occasions amounted to 250.

Several official bulletins and leaflets have been revised during the year, in collaboration with the N.A.A.S. Fruit Group. In addition three popular articles have been written and assistance given to the B.B.C. in recording a series of talks on various aspects of research for overseas broadcasts. The Index to the Station's Annual Reports has been extensively revised and is almost ready for the printers.

Seven lectures, mainly in Kent, were given to fruitgrowers, gardeners, and students. Exhibits were staged at the Marden Fruit Show, the Chelsea Flower Show, the Kent Cherry and Soft Fruit Show, and at the Linnean Society for the President's Reception. Help was given in staging a part of the Barley Mow exhibit of the Barley Advisory Committee at the Kent County Show.

The usual lectures on science and horticulture were arranged for the plantation assistants, and farm walks of the research station and selected growers' holdings for members of the research staff.

Research has proceeded on the storage quality of apples (see page 39), peach culture, and root excavations.

Publications During the Year

T54 Walker, J. H., and Couch, Gwendoline A. (1955). **The pruning of fan-trained peach trees.** *Fruit Year Book 1956*, 1955, 89-92.

T57 Montgomery, H. B. S. (1956). **Abstract on: Growth and flowering of fruit trees.** *N.A.A.S. quart. Rev.*, No. 31, 27-9.

T58 Walker, J. H. (1956). **Rootstocks.** *Fatis Review Supplement* 5, 4-5.

XI. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

By H. B. S. MONTGOMERY

Apple manurial trial

A further series of storage comparisons at 32° F. and 37° F., as in 1954-55, was made with the Cox's Orange Pippins from the manurial trial. The comparisons suffered from the fact that the crop was very light on some of the treatments especially where the swards received no nitrogen, but the main effects of swards in reducing rotting, and of nitrogen in increasing rotting were confirmed. Flesh breakdown was reduced by potash.

Determinations of cell size were made on cortical tissue of samples of 25 apples per tree from a range of the treatments. The larger fruits were composed of the bigger cells so that data were adjusted for fruit size and showed a tendency for fruits grown with low nitrogen to have slightly smaller cells. These fruits also showed a lower respiration rate, as determined on similar samples at Ditton Laboratory. The chemical analyses of fruit from all the treatments were again made at Ditton Laboratory.

Soil management trial

This was an off year for many of the trees of Laxton's Superb on M.II in this trial. Storage comparisons were made at 32° F. and 37° F., and the fruits grown with straw mulch showed a higher percentage of rotting than those with grass or arable. Parallel determinations of chemical composition and respiration rate were made at Ditton Laboratory ; the respiration rate of arable-grown fruit was lower than that of fruit from either the grass or the straw mulch treatments, but this result, at variance with previous experience of this trial was probably influenced by the off-year condition of many of the trees.

Pruning

Fruit was obtained from both Laxton's Superb and Cox's Orange Pippin on M.II in a pruning trial and stored at 32° F. and 37° F. The Superbs from Renewal pruned trees showed less rotting than those from Established-spur pruned trees, and a tendency to less than those from Regulated trees. With Cox's Orange Pippin, fruit from Established-spur pruned trees showed less rotting than from Regulated trees. Differences in the incidence of bitter pit were not clear cut but there was a tendency for less bitter pit with the Established-spur treatment ; this trend is the reverse of that observed in 1954-55.

No significant effects were recorded for storage breakdowns.

Fruit thinning

The crops produced by trees of Sunset on M.IX in a thinning trial were too small and variable to provide adequately replicated storage comparisons, but samples stored at 37° F. from the unthinned control and the earliest thinning probably had less rotting than those from the latest thinning.

Commercial samples

Samples of Cox's Orange Pippin were again obtained from nine orchards in Kent, Sussex and Essex, seven of which were the same as in 1954-55. These were stored at 32°, 37° and 50° F. and examined at intervals for wastage.

The degree of rotting in the various samples did not agree in every case with that recorded in previous years and with the known history of the orchards ; it is possible that the size of crop may be a variable complicating factor. Chemical analyses have been carried out on all these samples by the Ditton Laboratory.

The samples this year were made up in bags of 25 apples, two bags being used for each examination; close agreement was obtained between each pair.

Survey of commercial fruit

A further series of over 100 samples of Cox's Orange Pippin were assembled and subdivided for storage, in air at 37° F., and in gas at 3 per cent oxygen and 5 per cent CO_2 at 38–39° F., at the Research Station. The fruit from cold store was examined on 23rd January and from gas store on 20th February;

gas storage enabled the majority of the samples to be kept for one month longer than cold storage without any increase in losses through rotting.

There appeared to be slightly less rotting and bitter pit in fruit from grass, and high levels of applied potash in this season also seemed to reduce these troubles to some extent. Fruits from trees over 20 years old or from orchards where the crop was below 200 bushels did not keep well ; in general large apples developed more troubles than smaller ones. The indications from this trial with regard to the effect of the orchard history of the fruit were, however, complex, partly because of the difficulty in assessing the nutritional levels existing in each orchard from the information on the nutrients applied. A chemical analysis was therefore carried out by the Plant Analysis Section on fruit from each of these samples but the results have not yet been fully examined. In the series of samples put in store in the autumn of 1956, much fuller information is being collected. There was some evidence that a scab spray programme based on captan gave a lower percentage of *Gloeosporium* fruit-rot than one based on sulphur.

Other investigations

Numerous controlled pollinations of labelled blossoms of Cox's Orange Pippin, Beauty of Bath and Edward VII were made to provide material for detailed examination of embryo development in relation to cell division in the swelling fruitlet, and for sending to the Biophysical Laboratory of Leeds University for the study of cell and cell wall constituents throughout the growing season. Further samples are being sent after periods of storage at 37° F. Preliminary examination of fruitlets of Cox's Orange Pippin showed that cells were still dividing in the cortex, and that the endosperm was still in the multinucleate condition 30 days after pollination, whereas in specimens of Sunset collected in a previous season few cells were dividing after 23 days and the endosperm had become cellular.

Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

THE PLACE OF PLANT PHYSIOLOGY IN FRUIT GROWING

By Professor F. G. GREGORY, D.Sc., F.R.S.

It is a privilege to be invited to give the Amos lecture, and it is no easy task to emulate the high standard set by previous lecturers. All but one of the previous contributors may rightly be claimed as experts in their own fields of horticultural science, an advantage which I lack, and this I hope will not become too apparent in the course of my address. Professor Bennet-Clark in the 7th Amos lecture showed how close is the link between the study of water movement in trees, a classical problem in plant physiology, and many of the field problems encountered in the culture of fruit trees. The title which I have selected should have forewarned you of the academic approach which I feel compelled to adopt, but there is a further reason why I have chosen to speak of the contribution which plant physiology can make to the advancement of pomology. I regard this address as an opportunity for paying tribute to the great service that Professor V. H. Blackman, F.R.S., has, over a period of many years, devoted to the work of East Malling, and to the development of plant physiology as an applied science. It is not an exaggeration to say that before the first world war plant physiology was essentially a laboratory science in which the various functions of the plant such as nutrient uptake, assimilation, transpiration, and trophic reactions were studied as isolated processes, for which purpose separated organs were enclosed in complicated apparatus, and all the resources and exact methods of the physical sciences were exploited. This kind of experimentation was, and still is of course, essential to provide the basis for understanding the functioning of plants, but it disregards the fact that these various processes in nature are interrelated to constitute a functional unity. Each organ such as root, stem, and leaf is the seat of specialized activities, but these all interlock and find their combined expression in the growth and development of the plant. The recognition by Professor Blackman of the need to study the ' plant as a whole ' has led to new possibilities for the application of plant physiology to the practical problems of horticulture and agriculture. The publication in 1919 of the paper entitled ' The Compound Interest Law and Plant Growth ' marked the beginning of a new advance. It was my singular good fortune that at this time I was beginning my research career having recently completed my apprenticeship, if I may so call it, as an undergraduate at the Imperial College and as postgraduate at Cheshunt Experimental Station. At that time Professor Blackman had gathered together a band of research workers whose names are familiar to you all ; I will here only mention William Brown and R. C. Knight. I need not enlarge on Brown's contribution to the new science of physiological pathology. I wish particularly to stress the practical ends to which this work was directed. Of Dr. Knight's work I shall say more later.

The Imperial College is, as you all know, an urban institution far removed from the countryside, and at that time was without any facilities for field work. To meet this difficulty Professor Blackman urged the Ministry to establish an Institute of Plant Physiology with the set purpose of bringing the work of his department into contact with neighbouring research institutes, in which, at that time, there were no plant physiologists employed. In pursuit of this policy members of his research team were delegated ; Dr. Knight to East Malling, and I myself first to the Cheshunt Experimental Station, and later to Rothamsted Experimental Station. From these small beginnings the Institute has gradually developed, and the contacts with the outside research institutes have been maintained to the present time. This co-operation has worked well and to the advantage of all concerned. In this way the gulf between academic research and applied research in plant physiology has been bridged.

In academic circles a regrettable distinction is still often made between so-called ' fundamental '

* The ninth Amos Memorial Lecture, delivered at East Malling Research Station on 15th November, 1956.

and ' applied ' research. As Dr. Tukey in the fifth Amos lecture put it : ' The terms " fundamental " and " basic " are employed often with the connotation of superiority.' Whatever the situation may be in other sciences, in horticultural science such a distinction is quite out of place. Many of the essential techniques such as budding and grafting were known from remote antiquity, and a vast body of empirical information had been accumulated by the experience of practical men and awaited scientific analysis. The grower poses the questions and occasionally the scientist can provide the answers. Plant physiology is, I think, unique in that one can precisely date its origin as a science. I refer to that remarkable book *Vegetable Staticks*, written in 1727 by Stephen Hales, incidentally a Kentish man, who as perpetual curate at Teddington carried out experiments in his garden. Bearing in mind the discovery of the circulation of blood in animals by William Harvey in the previous century, Stephen Hales sought for evidence of a circulatory system in plants, and by ringing experiments established the downward flow of sap in the bark, and by injecting dyes the rising water stream in the wood. He showed that by activity of the roots water was forced upwards into the stem and he measured directly this so-called root pressure, an experiment still carried out in every teaching laboratory, and a phenomenon of which the cause is still debated. Even more remarkable is the conclusion he came to that much of the nutriment of plants is drawn from the air, thus foreshadowing the discovery of the assimilation of carbonic acid by the leaf—the source of the wood, starch, sugars, and other organic substances in plants. Unfortunately this pioneer work was forgotten until rediscovered by the great German physiologist Sachs, who during the last century enlarged the scope of plant physiology to its present extent.

In the interval the foundations of modern chemistry had been firmly laid, and during the closing years of the 18th and the opening decade of the 19th centuries it became possible to identify the chemical elements of which the plant body consists and the whole field of plant nutrition was opened to study. This new knowledge was immediately applied in developing the use of artificial fertilizers particularly by Lawes and Gilbert at Rothamsted ; a new industry was founded and the new profession of agricultural chemist arose. Curiously enough this new science of plant nutrition was not regarded as plant physiology but was handed over to agriculture, and the method of field experimentation was the main avenue of advance. I must, however, qualify this sweeping assertion by referring to the pioneer work of Sachs who in 1858 published an account of his method of water culture. Plants were grown in solutions of supposedly pure salts and by omitting in turn various chemical elements the effect of their deficiencies on plant growth was studied. In this way certain elements came to be regarded as essential, namely C, H, O, N, P, S, K, Ca, Mg, and Fe. It is noteworthy that at this time Sachs had already identified the importance of iron in overcoming chlorosis in plants, and thus established the importance of one of the trace elements. If the chemicals at his disposal had been really free from contaminants there can be little doubt that the role of other trace elements would have been discovered nearly a century ago.

We are now in the midst of a second period of rapid advance comparable in importance with that of the early 19th century, and equally dependent upon advances in chemistry. Now, in place of the various chemical atoms, the nature and structure of the varied organic molecules in plants is the subject of investigation by organic chemists, and the part they play in the chemical mechanisms of the cell and their mode of action by the biochemists. They are often present in minute amounts but the new methods of chromatography enable them to be separated, and by the use of radioactive isotopes quantities of the order of the millionth part of a gram can be estimated with accuracy.

Of such organic substances the most appropriate class to mention here is the growth hormones or auxins, which participate in such diverse activities as extension growth, root formation, stem thickening, leaf and fruit fall and fruit setting and development. Whereas a few years ago only one such hormone occurring naturally was known with certainty and its chemical structure determined in the last few years others of quite different types have been isolated from plant tissues. Synthetic substances resembling auxin in structure followed and these have found wide application as root stimulants in propagation and as weed killers. In addition, there are the vitamins of the B class common to plants and animals, such as thiamin, nicotinic acid, and pyridoxine, all of which are known to be essential for the growth of roots. The isolation of specific organ-forming substances foreseen by Sachs is almost in sight. Already there is good circumstantial evidence for the existence of special flower-forming hormones which Professor Stoughton dealt with in the sixth Amos lecture ; control of plant development by the use of hormones is thus already within the range of possibility. In the present phase the field experiment has been replaced by tissue culture as the appropriate method of experimentation.

The plant physiologist is now confronted with a veritable feast of new knowledge ; it remains to be seen how adequately he will be able to digest it. The danger, as I see it, arises from the tendency towards extreme specialization leading to disruption of plant physiology as an independent science. This leads me back to my main theme. The ultimate aim of all these researches is to understand the

unctional organization of the plant. The plant body is composed of myriads of individual cells, which during growth continually increase in number by active cell division. These cells are grouped into societies with specialized activities, and constitute the different organs of the plant. Thus the oot is concerned mainly with uptake of water and nutrients from the soil ; the leaf is responsible for he assimilation of carbon dioxide from the air, the stem acts as a mechanical support for the leaves nd is concerned with the transport and interchange of materials between the roots and leaves, and the ower by seed formation ensures the perpetuation of the species. Each organ, as the microscope hows, has a complex structure of different tissues ; thus the stem consists of wood and bark separated y a cambium, which continually adds new cells and so leads to stem thickening. The wood again onsists of storage cells as well as the vessels which transport water, while the bark consists of the xternal cork, a protective layer of dead cells impervious to water, and includes a special tissue, known s the sieve tubes, in which organic materials are transported. There is thus a ' division of labour ' etween the various organs and tissues of the plant, and all these must act in harmony to ensure growth nd development ; this is what I mean by functional organization. Growth is thus the fundamental haracteristic of the living plant, and therefore the study of growth must be regarded as the focal oint of interest of plant physiology. For this reason the study of the plant as a whole is of such mportance, and, as I have already said, this line of work began with the publication of Professor Blackman's classical paper in 1919. To introduce a discussion of this subject let us examine the asic idea expounded in this paper on the Compound Interest Law of plant growth. As is well known o you all the plant seed contains an embryo, which in effect is a miniature plant with the rudiments f stem and root already present, and in most cases a store of reserve nutrients. When germination f the seed starts the growing points of the root and shoot become active and cell multiplication begins, nd at the same time by uptake of water the cells already present rapidly enlarge so that the rudi- nentary roots and leaves extend and emerge from the seed coat. At first this development takes lace in darkness in the soil, so that whereas the root as soon as it emerges begins to absorb soil nutrients nd water, the leaves on the other hand cannot function in their capacity of absorbers of carbonic cid, as light is required. The products of leaf activity, namely, sugars and starch, are required for wo purposes : first to provide the carbon which together with the nitrogen absorbed by the roots is vorked up into protein, and secondly to provide the energy required to drive the chemical mechanisms nderlying all cell activity, particularly in the growing regions.

At first then the growing seedling is dependent on the starch, sugars, and/or fats stored in the eed reserves. Later, of course, as soon as the leaves are expanded above ground they begin to syn- hesize carbohydrates which are transported to the growing points of stem and root. Part of this naterial is immediately used to produce further roots and leaves and this process continues. The irst estimate of the rate at which this accumulation of materials occurs in the growing plant is made y simply measuring dry weight increase. From this point of view the original dry weight of the embryo may be likened to capital invested bringing in returns at compound interest. Indeed this is he concept that Professor Blackman introduced. The final amount of dry material accumulated n a given time will thus depend first upon the original capital (i.e. the embryo weight), and secondly pon the rate of interest. The absolute rate of accumulation at any time after germination will there- ore be dependent on the amount already accumulated just as in the financial situation. The percen- age rate of accumulation was called by Professor Blackman the ' efficiency index ' ; it is now generally eferred to as the ' relative growth rate '. If one now considers a series of related species (data of unflower species were used by Professor Blackman) having different embryo weights, then one would xpect that the plants with the bigger seeds and embryos should produce the heavier plants. This vas by no means always true, as the duration of the growth period up to seed formation differed among he species. When, however, this was taken into account by calculating the rate of increase per day r week the efficiency indices were nearly constant. Thus, to quote actual cases: a dwarf species vith a seed weight of only 0·001 g. produced a final weight of 6·9 g. in 107 days, whereas a giant form vith a seed weight of 0·019 g. produced a final weight of 235 g. in 116 days. The ' rate of interest ' n the dwarf was 8·25 per cent per day, in the giant 8·30 per cent. By contrast, another dwarf species vith a seed weight of 0·035 g., i.e. twice that of the giant species, produced a plant weighing 129 g. n 90 days, and the rate of interest or relative growth rate was 9·13 per cent per day. Thus the elative growth rate was much less variable than either embryo or final weight. Here then was a neans of comparing directly the efficiencies of various plants as growing concerns.

This, as I have said, marked the beginning of a mode of study which has come to be known as 'growth analysis '. So far we have considered only the net accumulation of dry material by the plant : he analysis can, however, be carried much further. The main increase in dry material of the plant s due to carbohydrates, mainly wood and storage starch or sugar. All this material has come from the arbonic acid of the air through the activity of the leaves. Now suppose one knew what the area of he leaf surface was day by day, then between any two occasions on which a population of growing

plants was sampled for dry weight, the average area of the leaf surface would be known. The increase in weight of the sampled plants would give an estimate of the amount of material formed by a unit area of leaf surface during the period between samples. Through this area all the carbon dioxide taken up by the leaves will have entered the plant, and therefore, since the composition of carbohydrate is known, it is a simple matter to calculate how much carbon the plant has assimilated, and therefore also the rate of assimilation of carbon dioxide. This is a very important aspect of plant activity. It has been named the ' net assimilation rate ' (N.A.R. in short). It measures the rate of utilization of CO_2 and may be defined as so many grammes of CO_2 per square decimeter per week. The first time this kind of analysis was done was in the course of my work on the seasonal variation of growth of cucumbers at Cheshunt Experimental Station during the first world war—in fact it was the first piece of research I was entrusted to do.

I ought to mention that in measuring the dry weight increase correction must be made for the ash and protein content and this means a lot of chemical analysis : but this is a detail which I add to avoid misunderstandings. The technical details as to how the leaf area is measured I must omit—but it is obvious that if one wanted to estimate the N.A.R. of growing trees this would present great difficulties, so that small plants are preferable. It is, however, essential to measure the rate of growth of the leaf surface, and this is again a most important aspect of growth ; it is measured in terms of the relative growth rate of the leaf surface, or leaf growth rate. Of course there are many other characteristics of the plant which can be measured. Thus the total dry weight can be partitioned into weights of root, stem, leaf and fruit, and so the distribution of growth between the different organs ascertained. All this is important information, and gives numerical expression to the varying form of the plant as it grows. Also if one analyses the dry material for the different chemical elements one can study the rate of uptake of the major as well as the trace elements, and so learn much about the activity of the root system, and how this changes with age and during the growing season. Growth analysis thus enables one to study the relation of the main growth processes to weather conditions, to nutrient and water supply in the soil, to cultural treatments of all kinds, and moreover this can be done using the plants in the field under natural conditions. The practical value of this kind of study has been shown by the work of Crowther on cotton under irrigation in the Sudan, by Heath on rain-grown cotton, by G. E. Blackman at Oxford and Watson at Rothamsted on various agricultural crops. The work carried out in the Institute of Plant Physiology in this field, mainly in the study of the barley plant, is to be found in 18 published papers under the title Physiological Studies in Plant Nutrition.

I hope I shall not try your patience if I say a few words about these researches. When I was delegated to work at Rothamsted in the very early days of the Research Institute the problem I set out to investigate was this : how are the large increases in growth and yield obtained by the use of the major nutrient elements, N, P and K, in artificial fertilizers actually brought about. It was, of course known that the main effect of nitrogen manuring is to be seen in the darker green colour of leaves and this green pigment, chlorophyll, was known to act by absorbing the energy of sunlight and making it available for the synthesis of sugars in the leaf. Is the larger growth due to this increased content of chlorophyll and so to a more active assimilation of CO_2 ? Growth analysis demonstrated that the N.A.R. of the leaves was not affected but that the greater yield was due entirely to the higher leaf growth rate resulting from increased nitrogen supply. Phosphorus on the other hand was shown to increase the N.A.R. and potassium had an even greater effect. This is a simple example of the method in action.

I must turn now to the bearing of what I have previously said on the physiological work at East Malling, and in particular to the researches begun by Dr. Knight.

One can follow the development of the work by reference to the summaries of the Annual Reports of East Malling. Thus, in 1919–20 one reads that Dr. Knight ' is now coming to East Malling for considerable periods to collaborate with the staff on the many physiological problems involved in root influence '. The double working experiments were begun at this time. In 1920–21 a physiologic study of the different stocks and root systems was begun with the object of arriving at more certain and scientific methods of selecting the best types of stock for economic use. The related problems of propagation were begun forthwith. In 1922 we read, Dr. Knight ' is now giving his undivided attention to physiological problems raised by rootstock investigations at East Malling ', and that arrangements were made for him to make East Malling his headquarters, while still remaining under the direction of Professor V. H. Blackman. Dr. Knight reported that a ' remarkable likeness in physiologic behaviour has been found even in stocks as widely different in their influence on scions as Type [M.]I and [M.]IX '. Field experiments were undertaken to discriminate between quantitative and qualitative factors in the rootstock influence, and to decide ' whether the absorbing roots, the conductory portion of the root system or the small piece of the stem of the stock is chiefly instrumental in inducing scion variations '. In 1923 Knight reported that ' no evidence has yet been obtained

suggest that the difference between the water relations of the two stocks (M.I and M.IX) are transmitted to the scion ', and further that such differences as occur between the stocks are small. The differences mentioned refer to the rate of conduction of water through the stems under a known head of pressure and the rate of water loss (transpiration) from the leaves. It would appear therefore that the water relations were not regarded as the clue to the problem.

In 1924 further efforts were made to ascertain whether quantitative nutritional factors are operative ; to this end the following experiments were begun. First, trees with several buds of the same scion worked on one stock were employed ; secondly trees consisting of two root systems of different varieties and one scion were used, and thirdly, double worked trees with a piece of a stock as intermediate were investigated. I shall briefly discuss the findings in these experiments as reported in 1927.

1. Trees worked on Type M.IX are dwarfed but precocious ; on Type M.I. vigorous but late in bearing. Instead of a single bud of Lane's Prince Albert three such buds were worked upon stocks M.I and M.IX, together with controls with a single bud. If supply of materials from the stock were the important factor in determining vigour it would be anticipated that such supply would be less when divided between three scions than when available to a single scion bud. It was found that the amount of wood growth on both stocks was greatly reduced by multiple budding, whereas precocity was unaffected. Vigour thus appears to be due to quantitative factors, and precocity to qualitative factors.

2. When rootstocks were inarched and combined in pairs with a single scion of Lane's Prince Albert the vigour of the scion on the pairs M.I and M.IX was intermediate between that of scion on combinations of stocks M.I and M.I, and M.IX and M.IX, indicating a quantitative effect of the stocks. On the other hand scions on the pair M.I and M.IX were about as late in flowering as those on M.I and M.I ; precocity effects would thus appear to be qualitative.

Thus it is clear that Knight clearly discriminated between two aspects of the stock-scion relation, namely nutritional or quantitative effects on vigour, and qualitative effects on flower induction or precocity.

So far as the first aspect is concerned rapid progress was made. The outstanding discovery may be summarized in Knight's own words : ' when dormant buds break into new growth in the spring the new xylem (wood) appears first in regions bearing such developing buds '. A wave of cambial activity leading to stem thickening passes down the stem, and each bud as it breaks into activity contributes to the total effect. Unpublished data show that the rate of travel of the wave of thickening is of the order of one inch per day above ground, but below ground is very much slower (about $\frac{1}{12}$ inch per day) and by the end of the growing season may fail to reach the base of the underground portion of stem, which results in the reverse taper below ground. Cambial activity in the root was also studied and it was found that thickening in the root may begin from the distal end and work up towards the stem, and a gap with no thickening may intervene. The use made of these observations by Knight and later by Dr. Vyvyan in the elucidation and rationalization of pruning techniques is outside the scope of this address.

Before taking off from the solid ground of fact for a flight into the realms of speculation, I must refer to some other important results published by Knight in 1934. A variety of scions worked on a number of rootstocks was studied, as well as some unworked rootstocks. The young trees which were planted without roots were subjected to a very wide range of pruning treatments. Almost without exception, among the 500 trees used, it was found after one year's growth that severe pruning led to an increase in shoot production and a reduction in root production. The new growth of the aerial portion was divided into material added to the old stem as thickening and the new material incorporated in the new shoots. In every case, the *increase* in shoot growth resulting from pruning was accompanied by a *decrease* in new tissues added to the old stem. It thus appears as if active competition occurs between the sites at which carbohydrates are used. Finally, the very important result was established that independent of the degree of pruning, the ratio of the new stem tissue to the new root tissue is substantially constant.

All the facts presented bear on the problem of the stock-scion relation, and it is to this topic that I will confine my attention. When Knight spoke of quantitative nutritional factors he made it clear what he had in mind ; namely the carbohydrates necessary for root formation supplied by the leaves, and the nitrogen and mineral elements required for top growth provided by the absorption processes of the root. Since nitrogen supply is the main factor regulating the leaf growth rate, and thus the area of assimilating leaf surface, it is obvious that the nitrogen supply (and other essential elements) will determine the supply of carbohydrates to the roots and thus regulate the expansion of the root system. This natural regulation leads at once to the observed fact that the ratio of root weight to shoot weight tends to a constant value. This is adequate as a first hypothesis, though as Knight realized it is subject to reservations.

First, the ratio of shoot to root varies with the root stock used : thus from Knight's data for stock M.X with various pruning treatments values ranging from 79 to 82 per cent represent the new shoot growth as percentage of total growth made, which corresponds with a mean shoot/root ratio of 4·0 ; the corresponding values for stock M.I range from 74 to 78 per cent with a mean shoot/root ratio of 3·1.

Secondly, it is tacitly assumed that the relation between shoot weight and leaf area is constant, and this need not be so, since on short spurs the leaves are crowded and little stem is formed, in contrast with the widely separated leaves on leaders and strong lateral shoots. Everything depends on the relative numbers of these two types of shoot formed under a given treatment.

Thirdly, the relative vigour of two stocks, worked or unworked, may be drastically changed by the nutrient level at which the trees are grown. Quite evidently the level of nutrient supply demanded investigation, and I shall later return to this question.

Let us first again consider the hypothesis put forward to account for mutual regulation of shoot and root growth. It is at this point that one of the unsolved problems of plant physiology enters in. Interchange of materials between leaf and root takes place by two paths ; first the salts of nutrient elements which in solution pass through the wood with the transpiration stream ; and secondly, organic materials such as carbohydrates and soluble nitrogen compounds which are conveyed as the descending sap in the bark along the channels of the sieve tubes.

The rate of transport in the bark is far greater than can be accounted for by any known physical mechanism, indeed the rate is of the order of 40,000 times as great as would be expected on the basis of diffusion of dissolved substances. We know that energy is required to drive the dissolved materials along, so that we speak of active transport ; and although we know that the energy comes from respiration of carbohydrates we do not know how the mechanism works.

Now, in the light of what I have said, let us consider the experiments with double worked trees in which a piece of a dwarfing stock is inserted as intermediary between the root and stem of a vigorous stock. This procedure, as is well known, leads to dwarfing to a greater or less extent depending upon the length of the intercalated piece of stem. If the rate of transport in the ' dwarfing stock ' is less than that of the vigorous stock, a ' bottle neck ' will arise at the junction of the vigorous and the dwarfing stem, and the flow of materials to the root will be impeded. In consequence root growth will be reduced, and as we have seen a constant ratio of stem to root growth is always maintained, so that stem growth will also be reduced due to the effect of the intermediate piece of stem. We ought therefore to seek to measure the intrinsic transport rate of dwarfing and vigorous rootstocks. In theory this could be done by the use of radioactive isotopes, but the difficulty is that a difference as small as 5 per cent in transport rate would account for the extreme differences in growth between stocks, and this is far too small a difference to be measured in this way. This possible explanation of stock/scion effect thus remains pure speculation.

Other possibilities must be considered, and I shall mention a few. First, plant roots display ' selective absorption ' that is to say that the nutritive elements present in the soil solution are taken up with differing ease. We now know that the trace elements such as copper, manganese, and molybdenum to name a few, play an essential part as catalysts in the chemical processes of cell activity, so that if the roots of the various rootstocks vary in their ' selective absorption ' the variations in scion behaviour may be accounted for in this way. This was the consideration which led to the spectroscopic investigations carried out by Dr. Roach, who indeed showed characteristic differences in trace element composition of various stocks. Again, specific organic substances may be formed in the roots and these when transported to the shoot may act either directly as growth promoters or inhibitors, or may be precursors for the synthesis of such growth regulators. The variation in production of auxin has been studied throughout the season and during the dormant period in stool-bed shoots of Crab C and Myrobalan B by Dr. Hatcher, and various growth promoting and inhibiting substances have been separated by chromatography by Barlow and Hancock and their properties are being studied. Whether the production of growth substances in the scion varies with the underlying rootstock is not yet known.

A great advance in the study of the differential response of various rootstocks to the major nutrients was made by Dr. H. L. Pearse who began work at East Malling in 1935. The method of water culture or hydroponics is particularly suitable for such work, but in the past great difficulties had been encountered in maintaining healthy growth of the plants. Under conditions of adequate aeration Pearse was able to grow successfully maiden trees of Cox's Orange Pippin budded on rootstocks M.IX and M.XII, dwarfing and vigorous respectively. He not only studied growth in fresh weight, in height, in leaf area and in diameter, but also followed the uptake of nitrogen and potassium throughout the growing season by analysing the culture solution in which the plants were grown. The usual differences in vigour appeared. It is interesting to note that the amount of water absorbed for each unit increase in weight was greater in the dwarfing than in the vigorous stock. The absorption

of both nitrogen and potassium per unit of weight was almost exactly the same in the two stocks, but there was a markedly greater uptake of potassium in the vigorous stock in the early stages. It is clear that nutrient uptake rate is not the clue to the stock-scion relation. The most remarkable result obtained by Pearse was the precocity of the trees on the vigorous rootstock which flowered and fruited nearly as freely as those on the dwarfing stock. After Dr. Pearse left for South Africa in 1938, this work on nutrition was taken up by Dr. Goodall, and a very ambitious programme was planned. Unfortunately, although aeration was provided the plants in water culture succumbed to bacterial infection of the roots.

After the war, work on stock-scion interactions in relation to level of nutrition was again begun by Dr. Bolas and Dr. Ruck. The first task was to master the technique of growing apple trees in water culture. After initial difficulties the key to success was discovered. It was found that the essential point is to prevent the stem of the plant being immersed in the solution, for under these conditions neither low pH nor aeration can prevent bacterial slime formation. This inevitably reminds one of the findings of Knight on propagation in which he showed that high water content of the soil prevents establishment, whereas in sand where drainage is good no difficulties are found. Our experience has entirely confirmed this, as in sand there was no loss of plants, nor in well-drained soil in pots.

Using the new technique the first experiment concerned the growth of two unworked rootstocks, Crab C and M.IX, at various nitrogen levels. At 5 p.p.m. of nitrogen a great difference in vigour of the stocks was found, the weights of Crab C and M.IX being 13·5 and 7·8 g. respectively. Note the difference of 5·7 g. in favour of the vigorous stock. At high nitrogen level of 200 p.p.m. the weights were : Crab C 45·6 g., M.IX 40·6. Note that the difference in weight was 5·0 g. Thus there is at the two nitrogen levels the same absolute difference in weight between the stocks, but the difference is 73 per cent at low nitrogen and 12 per cent at high nitrogen. At high nitrogen one would say there was no marked difference in vigour of the stocks, but a large difference at low nitrogen.

It was somewhat of a shock to find that the net assimilation rate (N.A.R.) was very much affected by nitrogen level, as this contradicted all previous experience with barley and cotton plants. At all levels of nitrogen, however, the N.A.R. of the vigorous stock was significantly higher than that of the dwarfing stock. This was a finding which demanded following up.

Experiments were then started using stocks M.XVI and M.IX grown at optimal nutrient level in soil and also in water culture. Comparing the N.A.R. over the whole growing season, the values in mg. per sq. cm. of leaf surface per day for plants in soil were :

M.IX 0·465 M.XVI 0·640 S.E. 0·026

For plants in water culture (at a lower nitrogen level) the corresponding values were :

M.IX 0·374 M.XVI 0·587 S.E. 0·021

This confirmed previous findings, and showed an overall difference in N.A.R. of 38 per cent in favour of the vigorous rootstock in soil and of 57 per cent in water culture.

These results were obtained with unworked stocks and therefore might well have been due to genetic differences controlling assimilation rate. To test this point the same two stocks were used budded with Cox's Orange Pippin. Growth analysis showed that the same differences in overall N.A.R. were again obtained. Thus the values for culture in soil were :

Cox/M.IX 0·533 Cox/M.XVI 0·653 S.E. 0·026

In water culture the corresponding values were :

Cox/M.IX 0·479 Cox/M.XVI 0·584 S.E. 0·021

In this case there can be no question of genetic differences in the scion, and the effect must have been due to the rootstock.

In the following year ten stocks of varying vigour were used for growth analysis. It was found that the N.A.R. values when arranged in serial order largely conformed with the order of vigour. Thus averaging the values for vigorous, intermediate, and dwarfing stocks the values of N.A.R. were : Vigorous 0·573, Intermediate 0·505, Dwarfing 0·460. The evidence strongly supports the overall higher N.A.R. of scions on vigorous rootstocks. How are we to explain this rootstock effect ?

One further set of data will conclude what I have to say. In 1955 two rootstocks were studied, namely Crab C and 3423, extreme examples of vigorous and dwarfing stocks. Instead of the N.A.R. being estimated over the whole growing season, in this case monthly samples were taken so that the change in assimilation rate with time could be followed. Over the period May to June the values of N.A.R. were : 3423, 0·67 ; Crab C, 0·72. Thus in the first month after bud burst there was no real difference in assimilation rate, but over the period August–September quite a different picture appears, for the dwarfing 3423 showed an assimilation rate of only 0·32, whereas the vigorous Crab C had a N.A.R. of 0·81. Compare these with the early figures and it is seen that the N.A.R. of the dwarfing stock had *fallen* by 52 per cent, while that of the vigorous stock had actually risen by 12 per

cent. As time advances the N.A.R.'s diverge more and more. This, I hold, is due to the more rapid senescence of the leaves on the dwarfing stock, and this conclusion is already foreshadowed by the work of Pearse who showed that up to July there was little difference in weight increase or leaf area of the rootstocks he studied, and the divergence began after this time both in weight increase and in leaf area, owing, I suggest, to the more rapid senescence and death of leaves on the dwarfing stock. The same conclusion may, I think, be drawn from the large effect of nitrogen level on N.A.R. already mentioned. Dr. Bolas has constructed an ingenious apparatus whereby the assimilation rate of leaves growing in the field can be measured, and thus we hope before long to demonstrate the truth of the conclusion we have reached. I should make it clear that in discussing the work on stock-scion relations I have confined myself almost entirely to the researches carried out by past and present members of the Institute of Plant Physiology, and therefore have not been able to do justice to the contributions in this field made by the staff physiologists of East Malling.

I have, I fear, covered only a small part of the subject of my address ; thus having raised the question of precocity I have left it. The reason may be attributed to blank ignorance. I trust, however, that I have convinced you all of the great possibilities inherent in the method of growth analysis for the solution of pomological problems. It only remains for me to thank Dr. Tubbs and all the members of the staff of East Malling for the help they have always afforded my colleagues of the Institute of Plant Physiology, and in particular I wish to record my gratitude to Dr. Pearse and Mr. Freeman of the statistics section who so patiently have taught us to avoid the pitfalls in the statistical analysis of our data.

I will end on a personal note. All those on the staff of the Institute of Plant Physiology, past and present, and also members of the staff of East Malling who can look back to happy and profitable days spent at the Imperial College will, I am sure, join with me in expressing our sincere thanks to Professor Blackman to whom we owe so much.

A SHORT HISTORY OF RESEARCH STATION LAND IN THE PARISHES OF DITTON AND AYLESFORD

By S. C. PEARCE and D. W. P. GREENHAM

The Research Station land in the parishes of Ditton and Aylesford may conveniently be considered in two parts :

(1) That to the west of Kiln Barn Road, and consisting of the present Egham Field, most of Kiln Field, and a small part of Church Fields East.

(2) That to the east of Kiln Barn Road, and consisting of the present Merryweather Field, Deadman Field, Newgates Field, Newgates Shaw, and Upper Grub.

There is also a small strip of land in Ditton parish down the east side of Plot P4 ; this appears for some time to have been treated like the adjoining parts of Bradbourne Park (see Pearce and Greenham, 1955), and will not be considered further.

As in the previous paper (Pearce and Greenham, 1955) names no longer in use or now used in a different sense will be written in italics.

The whole area, as it is today, is shown in Fig. 1.

1. Egham Field and Kiln Field

In 1789 (Map E) this area was occupied by two fields and parts of three others. The boundaries, as well as some later ones, are shown in Fig. 2. The *Maidstone Footway** crossed the parish boundary where it does now, but thereafter it lay to the south of its present line. There was a round feature, possibly a pond, on K7. The smallness of the fields deserves notice ; in Church Fields adjoining, the greatest fragmentation of holdings took place at about this time (Pearce and Greenham, 1955), and possibly this was general. The next map (F of 1801) gives little information, the field boundaries being perhaps conventional.

In 1842 (Map V1) *Kiln Field* included more than half of Egham Field ; westward it extended to the parish boundary, and southward for some distance beyond the present railway. The round feature on K7 had gone. The field was traversed by the *Maidstone Footway*, which crossed the East Malling–Ditton boundary as at present, but came out in Kiln Barn Road opposite the gap between Newgates Field and Ditton Laboratory. The area to the north of *Kiln Field* was called *Ditton Rough*, the boundary being a prolongation of one of those of 1789. The name recalls the entry for 18th April, 1602, in the diary of John Manningham, a relative of the then occupier of Bradbourne House (Manningham, 1868), as follows :

> *' My cosen concluded with William Tunbridge of Ditton to give him 115l for a leas of Ditton ruffe for 25 years.'*

Evidently the name was an old one and had survived some drastic boundary changes. According to the schedule of Map V1 (1842) both *Kiln Field* and *Ditton Rough* were arable. For *Kiln Field* this information is confirmed by the schedule of Map J (1844).

Map L of 1861 shows the *Maidstone Footway* as in 1842. To the south of it, an area corresponding roughly to Plots K6–8 was in hops, but the rest of Kiln Field was arable (Schedule of Map L). No information is given for the present Egham Field.

Mention should here be made of the homestead known as *Palmer's Rough* that stood on the east side of Kiln Barn Road opposite E30, south of the landway leading towards Aylesford parish. The main buildings first appear on Map J of 1844, and are shown again on Maps M, W1, and X of 1868, 1888, and 1891 respectively, but are omitted from Map N of 1897 and subsequent surveys. These buildings were not on Research Station land, but Maps M, W1, and X show further a barn or similar structure on the west side of the road in E30.

Map M of 1868 shows a row of trees down the parish boundary across K2–3, and also a tree on K7 by the roadside near the southern tip of K8. A tree on the parish boundary between C5 and E24 was also shown. The former boundary between *Ditton Rough* and *Kiln Field* had disappeared. The building of the railway in 1874 gave rise to the present southern boundary.

In 1897 again (Map N) there were no internal boundaries at all in the area except the *Maidstone Footway* ; it was also merged across the parish boundary with Great East Plantation, and this is

* This name is taken from Map B of 1706, which gives the designation *Maidstone Foot-Way* to the path from East Malling Church to the parish boundary. Its continuation eastwards is termed only *A Foot-Way*, but the map gives little detail outside the manor of East Malling.

confirmed by Map O of 1908. A document of 1904 (extensively quoted in Manuscript XVI) gives the total area of *Lower Ditton Rough and Great East* as 97·73 acres, of which 7·45 acres in *Lower Ditton Rough* was in hops. Judging from Map N of 1897 this total acreage refers to that part of the combined field lying in the parish of Ditton, i.e. excluding *Great East*. (Map Y of 1892 refers to the whole of the land between the railway and Ditton village as *Lower Ditton Rough, etc.*, and gives the area as 105·16 acres.) Manuscript XVI cites a conveyance of 1914 in which a field with the name of *Ditton and Great East* is described as being of 88·063 acres in extent, all of it arable. This would appear to be the combined field, less about 9 acres of fruit at the north end not on Research Station land that had been separated from it, because both the Field Number (90) and the area agree with Map O of 1908 for that part of the parcel lying in Ditton.

Egham Field was purchased in 1919. Its northern boundary is said to have been formed earlier. There is some evidence that the part of the boundary between Church Fields and Egham Field that is marked by a row of walnut trees lies at some points to the east of the parish boundary. On E30, as shown by Map R of 1932, the fence was at one time set back from the road, and passed over the site of the former barn.

In 1913 (Map P) the present boundary between Kiln Field and Great East was made, not along the parish boundary as formerly. It is said that the present trees on Kiln Field were planted in the same year. Map R of 1932 shows the trees, and also a shed opposite the entrance between K4 and K5. The field was acquired in 1933.

The name ' Kiln Field ' almost certainly derives from the kiln south of the railway. ' Egham ', on the other hand, is not an old name, but is said to come from Egham Hill, an alternative designation for that part of Kiln Barn Road adjoining the field.

After 1842 it is likely that Egham Field was arable until it was bought by the Research Station, and that Kiln Field was arable until 1913 apart from the hop garden which was at the eastern end for part of the time.

2. Merryweather, Deadman, and Newgates Fields, Newgates Shaw, and Upper Grub

The oldest available maps of this area, C and D of 1769 and 1778 respectively, are not sufficiently to scale for the location of the present fields to be determined, but the general picture is of woodland with an extensive clearing down the east side of Kiln Barn Road together with a long tongue of cleared land stretching towards Maidstone. Map E of 1789 is, however, much clearer. As appears from Fig. 3, which shows also some later boundaries, the *Maidstone Footway* went straight across Kiln Barn Road instead of following the northern boundary of the clearing, which was approximately the present southern limit of Ditton Laboratory. Near Newgates Shed the *Footway* met a path from the north, and then passed an irregular shaped field to the south, covering parts of N2–4 ; further to the east it ran across Newgates Field, Newgates Shaw, and Upper Grub.

The path met near Newgates Shed had a varied history. Its longest extent was from Mill Hall by way of Teapot Lane to Holt Hill and then on to join Kiln Barn Road at a cross-roads called *The Foure Wents* in Map A of 1699 and Map B of 1706. It will here be termed the *Teapot Lane Extension*. It is shown over its full length only in Map H of 1821, but other maps (D, E, F, V1, and J of 1778, 1789, 1801, 1842, and 1844 respectively) show parts of it. It ran across M3, N3, and N2.

In 1842 (Map V1) the clearing in the north-west corner of Newgates Field was somewhat larger than in 1789, and was arable with the name of *Newgate* or *New Gate* (Map V1 and its schedule). The land to the south of it was called *Coalpit Wood*, and the strip to the east *Newgate Wood*. The next field had acquired a straighter eastern boundary since 1821, and was called *Lower Knoxes* and was partly arable and partly in hops (Map V1 and its schedule); unfortunately no evidence has been found to show how it was divided. To the north of the *Maidstone Footway* the wood covering the greater part of Merryweather Field was known as *Palmer's Rough*, and a new field had appeared, partly on the present Merryweather Field and partly on Deadman Field, which was in hops with the name of *Deadman Hop Ground* (Maps V1 and V2 and their schedules). The *Maidstone Footway* is not marked on the Aylesford Tithe Map (Map V2) though it is shown on the Ditton one (Map V1), nor does the Aylesford map show the *Teapot Lane Extension* northwards of the *Deadman Hop Ground*. In the parish of Aylesford there was a new hop garden partly on Upper Grub (Map V2). Map J of 1844 shows *Newgate* to be in hops south of the *Maidstone Footway* with a narrow shaw to the north of it, and it indicates yet a further different eastern boundary of *Lower Knoxes*. It shows additionally a path leading eastwards from the *Deadman Hop Ground* across D2.

The next important map is that of 1861 (Map L). In this the *Maidstone Footway* still runs a little south of the present boundary of Newgates field, and a branch of it continues straight on into M3, but in the main it follows its present course and is shown as extending into Aylesford parish. The most important change, however, is the clearing of the whole area south of the *Maidstone Footway* apart from Newgates Shaw and the east end of Upper Grub. The west end of Upper Grub was in

hops, and the rest of the cleared land was arable (Schedule of Map L). The north-east corner of Newgates Field formed a separate parcel, though it is not clear that it was fenced off. The quarry is shown where the railway was later to cross Kiln Barn Road ; an extension to the north reached the present burning ground. The map gives no certain information about land north of the *Footway* except for showing woods east of the *Deadman Hop Ground.*

In 1868 (Map M) the *Maidstone Footway* appears as at present except for a few trees bordering it at the south end of M2 and M3. In Ditton no further boundaries appear on Research Station land ; the quarry is again shown. In Aylesford, there were only minor differences from the present. Thus, the east end of Upper Grub had been cleared, and there were two farm roads running across the field in an approximately north and south direction, the more easterly of these roads marking the former limit of the clearing. It went to a house that still exists south of the railway. In 1874 the railway gave the whole of this area a new southern boundary, and the more easterly of the roads across Upper Grub was of sufficient importance to have a bridge of its own (Map X of 1891, Map N of 1897), and this still exists. The 1868 map shows also that the whole of Deadman Field and some land to the east of it had been cleared, and it indicates a farm road across Deadman Field running almost due north from the north-west corner of Newgates Shaw, apparently marking the former boundary of the woodland (*Cf.* Map L of 1861). It shows also that Merryweather Field had been cleared.

Of the three maps available for the year 1888, Maps W2 and W3 and their schedules appear to be based respectively on Maps V1 of 1842 and V2 of 1843. They do not therefore provide reliable evidence as to 1888 except on the matter to which they specifically refer, namely, the alterations in tithe brought about by the building of the railway. Map W1 on the other hand appears to be based on an unidentified Ordnance Survey map, and confirms Map M of 1868.

Map N of 1897 again shows no field boundaries north of the *Maidstone Footway* ; the land to the east of Deadman Field is all shown as woodland. Only one road is shown across Upper Grub and none across Deadman Field. These points are shown in Map O of 1908 also.

In Manuscript XVI, reference is made to an indenture of 1904 and the plan that went with it (Map Z), neither of which has been seen in the original, from which various pieces of evidence emerge. Merryweather Field and Deadman Field together formed part of a larger area, 85·163 acres in Ditton and 40·275 acres in Aylesford, known as *Horse Leas and Palmer's Rough*, which was arable. The area to the east was called *Deadman Wood.* Newgates Shaw was woodland, and Upper Grub has its present name and was in hops. The west end of Newgates Field (13·700 acres), corresponding to N1, N2, and part of N3, was arable, and the remainder (12·856 acres) was in hops, the whole being called *Newgate Field.* The division is shown in Map O of 1908, which indicates also a path from Kiln Barn Road, round the burning ground and along the railway to the hop garden.

Manuscript XVI cites a conveyance of 1914 and subjoins a copy of the plan that accompanied it (Map AA)—neither original has been seen—from which it appears that field divisions, names, and states of cropping were the same as in 1904. A difficulty arises from the conveyance describing *Horse Leas and Palmer's Rough* as arable, whereas Map AA shows a hop garden at the east end of Deadman Field.

Manuscript XVI also refers to an indenture of 1925. There is no map, but it is reasonable to assume that the field numbers are those of the 1908 Ordnance Survey (Map O), then the current edition. At that time Newgates Field was all arable, so was Upper Grub, and Newgates Shaw was wooded ; other areas are not so easily identified.

Map BB of 1925 shows the easterly road across Upper Grub as still in existence.

The tale of the acquisition of this land by the Research Station is told in successive Annual Reports. Newgates Field was bought in 1927, though a long strip was left along the railway to provide independent access to Newgates Shaw and Upper Grub. These parcels, together with the strip and the burning ground were leased in 1929, Upper Grub being then arable (Manuscript XVIII). Deadman Field was acquired in 1935 ; and subsequently Merryweather Field was leased in 1937 (Manuscript XIX) at which time the Cox's Orange Pippin and Worcester Pearmain apples had already been planted in addition to strawberries. It was purchased in 1942. Map T of 1937 shows the landway between Deadman and Merryweather Fields. When Upper Grub and Newgates Shaw were purchased in 1952, the strip giving access to them was merged in Newgates Field, which now has the railway for its southern boundary. At the time of purchase of Deadman Field, D2 was already planted with plums, and hops had recently been grubbed from the remainder.

The conveyance of the land upon which Ditton Laboratory stands is dated 1928 (Manuscript XVII). Merryweather Bungalow to the north of it was leased and purchased by the Research Station at the same time as Merryweather Field.

The nomenclature of these fields has not been constant. ' Newgate ' is evidently an old name and has given rise to the modern ' Newgates '. ' Deadman ' probably had its origins in the hop garden of 1842 ; ' Upper Grub ' appears to be more recent. The name ' Merryweather ' for the field

comes from the bungalow, and this in turn is said to derive its name from the damsons that used to grow in its garden. There was a time in the history of the Research Station when Deadman Field was commonly designated ' Upper Deadman ' from an impression that Merryweather Field was properly called ' Deadman ', but this confusing usage appears to have died out after the acquisition of Merryweather Field. The old names of *Palmer's Rough, Coalpit,* and *Lower Knoxes* exist no longer for any land held by the Research Station.

Discussion

To the west of Kiln Barn Road the land appears to have been arable for a long time, and there is little evidence of features likely to cause trouble in designing experiments. There was the object on K7, the barn on E30, both near the headland, the hop-garden on Kiln Field, and sundry short-lived field boundaries.

On the other side of the road the history is of the gradual clearing of woodland for arable cultivation or hops. The boundaries have altered a great deal, and so have the paths and roads, and it would be extremely difficult to allow for them. The *Teapot Lane Extension* and also the eastern path across Upper Grub must have been of some importance, and their positions are fairly well defined.

Summary

A study is made of old maps and other documents relating to the land used by the East Malling Research Station for experimental purposes in the parishes of Ditton and Aylesford. Conclusions are based chiefly on the military survey of 1789, the tithe surveys of 1842–43, Ordnance Survey publications, and also the railway surveys of 1844 and 1861.

Acknowledgements

The authors are much indebted to the following for their help: Dr. F. Hull and Miss E. Melling of the Kent County Archives Office ; Mr. L. R. A. Grove of Maidstone Museum ; Mr. R. A. Skelton of the British Museum ; Rev. P. Scott, formerly Rector of Ditton ; Rev. H. J. Powell, Vicar of Aylesford ; Mr. A. McCrevie of the Aylesford Society ; and many members of the Research Station staff including Mr. T. N. Hoblyn and Mr. C. Bates. Thanks are also expressed to Mr. N. H. G. Munn of the Survey Branch of the Ministry of Agriculture, Fisheries and Food, who prepared the maps.

References

Manuscripts and maps have been numbered and lettered so that those referred to in the previous paper (Pearce and Greenham, 1955) may keep their original designation, and so that no numbers and letters are used twice.

Published books and papers :

Manningham, J. (1868). Diary of John Manningham, of the Middle Temple, and of Bradbourne, Kent, Barrister-at-law, 1602–1603. Ed. from the original MS. by John Bruce. (Camden Society publication).

Pearce, S. C., and Greenham, D. W. P. (1955). A short history of Research Station land in the parish of East Malling. *Rep. E. Malling Res. Sta. for 1954,* 54-63.

Manuscripts (other than maps):

XVI. Abstract of title to Merryweather Field and Bungalow, by R. V. and Marjorie Holme. *Copy in possession of the Research Station.*

XVII. Conveyance of the land for Ditton Laboratory from R. V. and Marjorie Holme to the Crown, dated 6th December, 1928. *Copy in possession of the Research Station.*

XVIII. Lease of Upper Grub, Newgates Shaw, a strip of land by the railway and the burning ground by Osborn Dan to the Research Station, dated 10th May, 1929. *Property of the Research Station.*

XIX. Lease of Merryweather Field and Bungalow from R. V. and Marjorie Holme to the Research Station for 21 years from 6th April, 1937. *Property of the Research Station.*

Maps :

A Map of Paris Farm, 1699. *Property of the Research Station.*

B The Mannor of Eastmalling. 1706. *Maidstone Museum.*

C Map of Kent by Andrews, Dury, and Herbert, 1769.

FIG. 1

Research Station land in the parishes of Ditton and Aylesford, October, 1955, showing plot boundaries and numbers.

Key to numbers in circles

1 Laboratories (E.M.R.S.)
2 Burning ground
3 Merryweather Bungalow
4 Ditton Laboratory
5 Newgates Shed

[face page 52

1789

1842

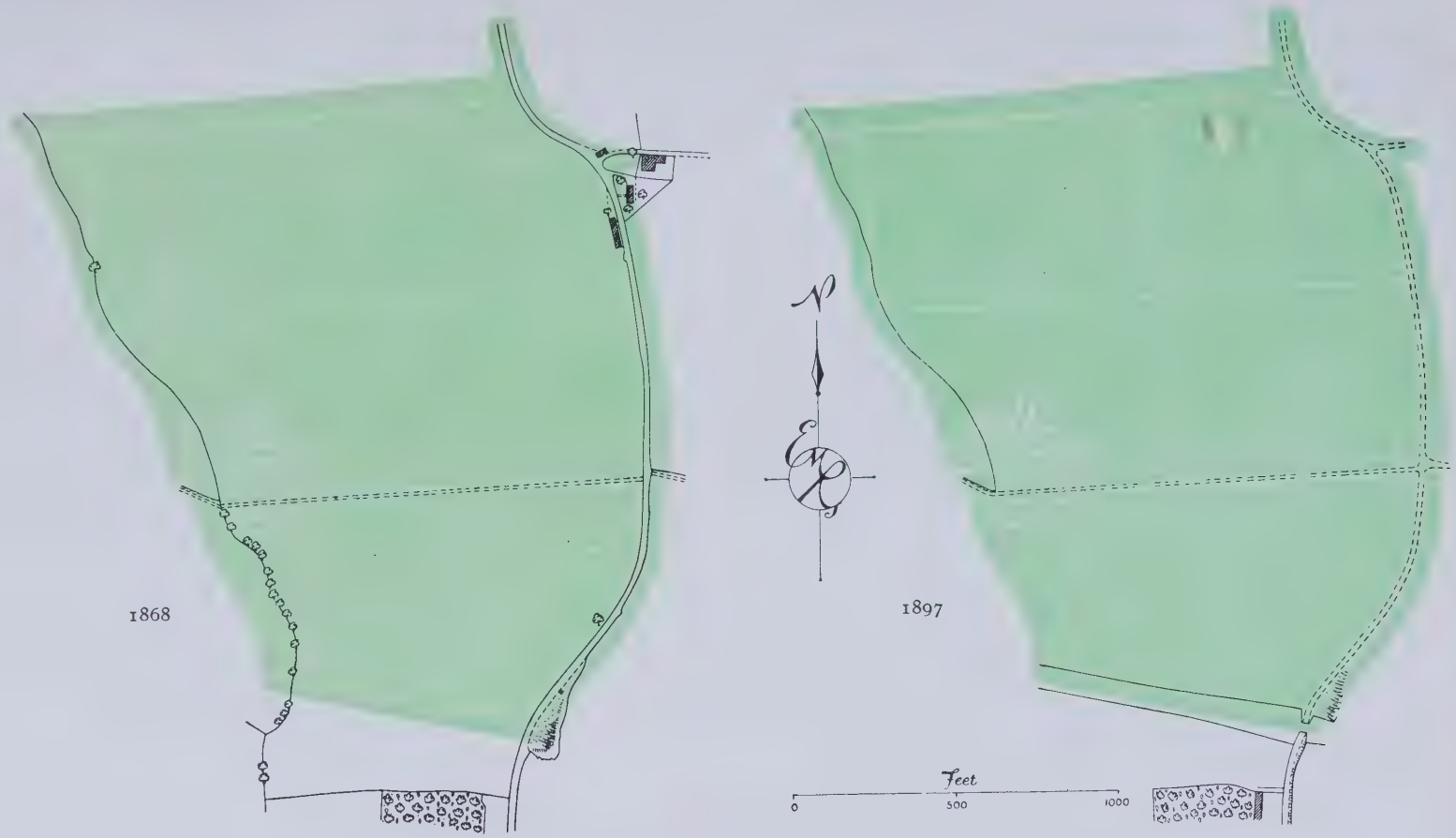

FIG. 2

The area now occupied approximately by Egham Field and Kiln Field, as it was in 1789, 1842, 1868, and 1897, outlined in black. Present plots, boundaries, etc., are shown in green and white

D Map 9 of Hasted's ' History of the County of Kent ', 1778.

E Military map of Kent prepared by Ordnance Survey, 1789. *Photographic copy in British Museum.*

F Map of Kent by Mudge, 1801.

H Map of Kent by Greenwood, 1821.

J Deposited map and schedule of Direct London and Maidstone Railway, 1844. *Kent County Archives Office : Q/RUm 259.*

L Deposited map and schedule of Sevenoaks Railway Extension, 1861. *Kent County Archives Office : Q/RUm 478 and 478B.*

M Ordnance Survey Map, 25 inches to one mile, 1868.

N Ordnance Survey Map, 25 inches to one mile, 1897.

O Ordnance Survey Map, 25 inches to one mile, 1908.

P Map accompanying conveyance of Great East Plantation, 1913. *Photostat copy in possession of the Research Station.*

R Ordnance Survey Map, 25 inches to one mile, 1932.

T Ordnance Survey Map, 25 inches to one mile, 1937.

V1 Map and schedule relating to an agreement for the commutation of tithe in the parish of Ditton, 31st July, 1841. Map signed as correct, 1st December, 1842. *Property of the Rector of Ditton. Copy in Kent County Archives Office : CTR 118A and 118B.*

V2 Corresponding map and schedule for the parish of Aylesford. Award made, 1st April, 1841. True copy confirmed, 9th May, 1843. *Kent County Archives Office : CTR 12A and 12B.*

W1 Map subjoined to a certificate of capital value of the Extraordinary Tithe Rent-Charge in the parish of Ditton, 11th September, 1888. *Property of the Rector of Ditton.*

W2 Map and schedule relating to the altered apportionment of tithe in the parish of Ditton, 29th September, 1888. *Property of the Rector of Ditton.*

W3 Map and schedule relating to the altered apportionment of tithe in the parish of Aylesford, 29th September, 1888. *Kent County Archives Office : CTR 12/4.*

X Ordnance Survey Map, one inch to one mile, 1891.

Y Map and schedule relating to the altered apportionment of tithe in the parish of Ditton, 8th December, 1892. *Kent County Archives Office : CTR 118/2.*

Z Map subjoined to an indenture between H. L. C. Brassey and T. Scott dated 10th November, 1904, and cited in Manuscript XVI with tracing of the map.

AA Map subjoined to a conveyance dated 26th October, 1914, and cited in Manuscript XVI with tracing of the map.

BB Map relating to the altered apportionment of tithe in the parish of Aylesford, 1925. *Kent County Archives Office : CTR 12/12.*

POMOLOGY

MIST PROPAGATION FRAMES FOR LEAFY CUTTINGS

By S. M. SINGH, W. S. ROGERS, and C. H. W. SLATER

Leafy cuttings are commonly raised in a closed propagation case in a glasshouse where, without frequent watering, the air may be kept moist. Transpiration is low and the tissues remain in the turgid condition needed for root formation. Rooting, however, must be rapid and is generally accelerated by the use of bottom heat, and often by the use of growth substances. A necessary feature is the regulation of light by shading, involving the constant attention of a skilled propagator.

Efforts to reduce these limitations are traceable to the experiments of Bayley Balfour (1913), who himself was following French practice. By very frequent watering, using a system operating in a closed case, he was able to admit full sunlight to the leafy cutting. More recently a fine spray or mist of water applied continuously or intermittently has been used (Snyder, 1954 ; Commonwealth Bureau, 1955). Automatic control is given either by a time switch or by a hydrostat (a moisture sensitive element)—the so-called ' electronic leaf '. Hydrostatic control is obviously the method most likely to avoid either drying or leaching of the leaves.

At East Malling the possibility of using mist propagation for rapid multiplication of newly-selected rootstocks was considered, and early in 1956 preliminary trials were made of the apparatus prior to the installation of a set of frames for use in the open.

Development of spray technique

Tests of nozzles

Following preliminary tests of various nozzles the Vaspra-Tegtmeier anvil type was selected. Water distribution tests were made in a glasshouse, the spray output being collected in open containers at measured distances. On leaving the nozzle orifice the jet of water is atomized by striking on a convex surface, the anvil, giving a fine spray directed upwards and outwards. It was found that the precipitation diminished rapidly with increasing distance from the nozzle. To achieve a more even distribution the anvil was flattened, and the advantage of this is evident from Table I. Accordingly, this modification of the nozzle was adopted.

TABLE I

COMPARISON OF NOZZLES WITH CONVEX AND FLAT ANVILS
SIZE OF NOZZLE, S10 ; PRECIPITATION, MM. PER HOUR, AT A WATER PRESSURE OF 30 LB./SQ. IN.

Anvil surface	Distance of centre of container from the nozzle (in.)				
	3	9	15	21	27
Convex	108·5	55·4	16·5	5·7	1·8
Flat	24·0	31·0	33·7	34·8	15·2

The second test compared nozzles differing only in the size of gap between orifice and anvil, the distances being 0·015 and 0·030 in. respectively. This revealed that the distribution of water is practically unaffected by small variations in the size of gap, though it was noted that for evenness of spread the jet of water should strike the anvil centrally and be wholly within the flattened area.

A study of three nozzle sizes, S10 (orifice 1·0 mm.), S15 (1·5 mm.), and S20 (2·0 mm.), in relation to water pressure, gave the results shown in Fig. 1. It was found that increasing the water pressure increased the effective field of spray, as did increasing the aperture size, though in the latter case it was accompanied by a progressive reduction in precipitation towards the nozzles. For covering a radius up to 2 ft. the small nozzle (S10) was most suitable ; beyond this distance there was a rapid decline in the amount of spray. It was desired, however, to cover an area 5 ft. square with the nozzle centrally placed, and for this the S15 nozzle gave the best distribution over the normal pressure range (30–50 lb./sq. in.). When pressure fell below 20 lb./sq. in. the area sprayed was much reduced, and below 8 lb. pressure the anvil was ineffective in producing a mist. At lower pressures, too, the supporting arm of the anvil markedly interfered with distribution and to alleviate this the two nozzles

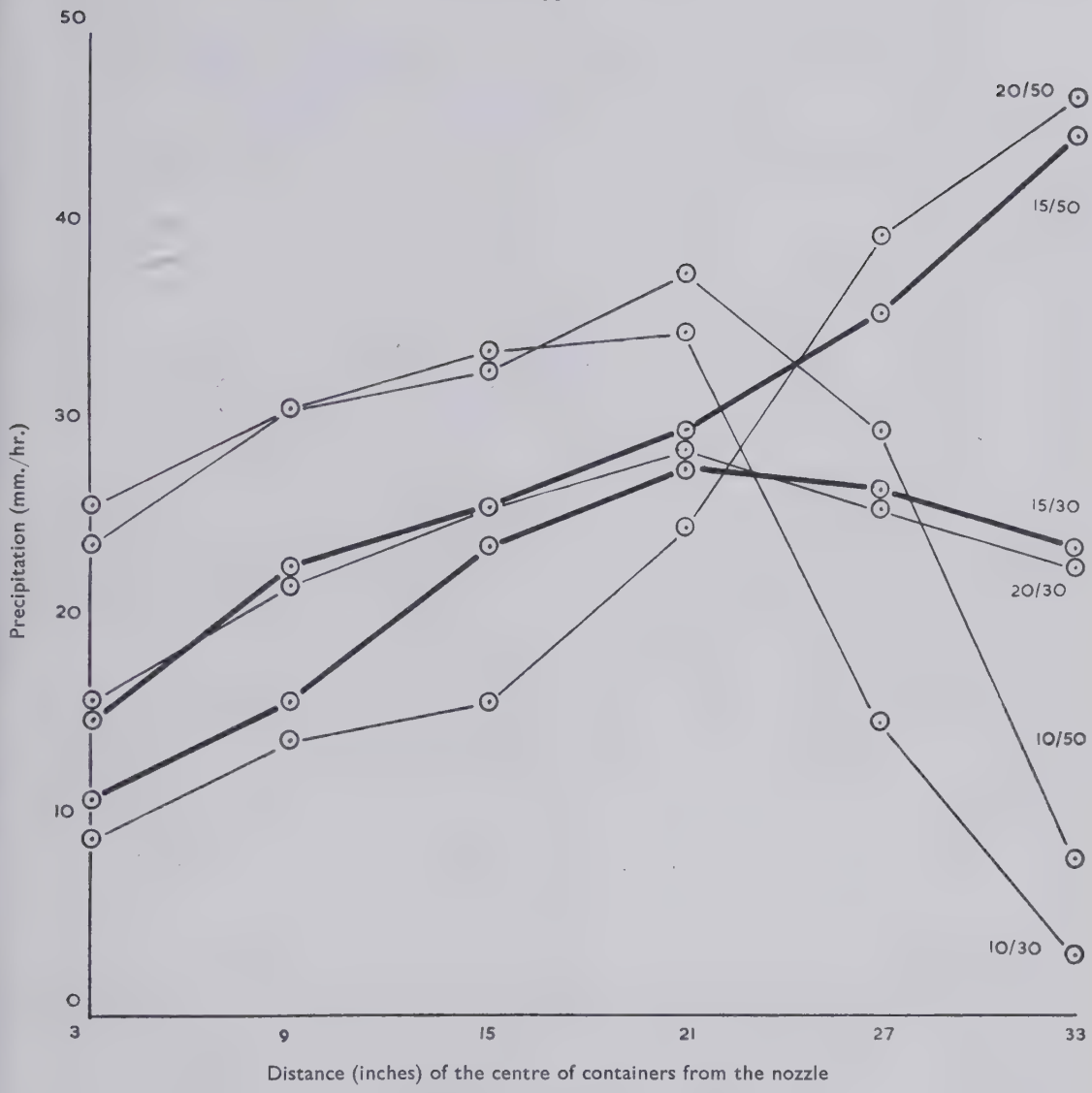

Fig. 1
Precipitation by different nozzles (sizes 10, 15 and 20) working at 30 and 50 lb./sq. in. water pressure

required for a bin area 10 ft. × 5 ft. were mounted with their supports almost towards each other ; so obtaining maximum overlap.

Finally the performance of the nozzles was observed in the open air in bins with side shields 3 ft. high. While light winds aided mist distribution there was considerable drift in a strong wind. As under cover, two S15 nozzles gave the most satisfactory distribution, and it was also noted that wind effect was eliminated when the bin was covered by shading material.

Automatic control of the spray line

The control mechanism, constructed at East Malling, consists of a hydrostat connected to an electronic relay which operates a magnetic water valve. The hydrostat (Fig. 2) consists of carbon electrodes mounted in an ebonite block. Insulated wires are soldered to brass caps on the carbons, and these connexions are sealed with waterproof insulating material. This unit is connected in the grid circuit of a triode valve, as shown in Fig. 3, and when the hydrostat is covered with a water film the valve cannot conduct. As the water film dries, the valve output operates a ' post office ' type relay, which controls the magnetic valve and thus releases water to the nozzles.

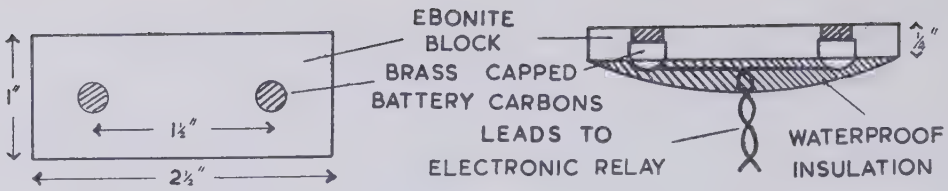

FIG. 2
The hydrostat

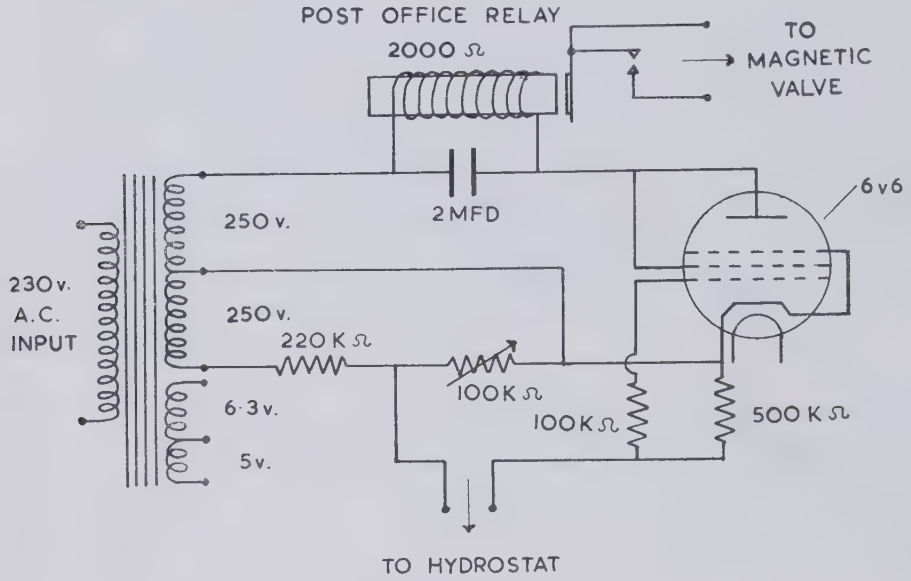

FIG. 3
Circuit of electronic relay

The amount of water required to close the hydrostat circuit is adjustable by a variable resistance (Fig. 3). The frequency and duration of the spray is also affected by the position of the hydrostat in relation to the nozzles. Tests were made to find the position that would most nearly maintain a thin water film on the cuttings. This was done by observing the changes in weight of pots of sand-peat mixture, and also the changes in volume of water in small cans, exposed in various parts of the bin.

It was found that the best position was normally midway between the nozzles and about 6 in. above them (Fig. 4). This position was least affected by wind direction. In very sunny or very windy weather, however, when more spray was needed, raising the hydrostat by as little as half an inch gave a sufficient increase of spray.

During all experiments with cuttings, water gains or losses were measured with open cans, as above, and the equipment was set to give a small net gain of water, so keeping the rooting medium at or slightly above field capacity, and maintaining the cuttings turgid.

Evaporation was measured for a period from cans in a bin receiving no spray. The water used by the sprays was recorded each day on a water meter. A recording pressure gauge, fitted in the spray line, showed that in sunny windy weather the sprays operated about once a minute, usually for about 2–3 seconds ; but on rainy days no spraying occurred for several hours. The quantity of water used varied from two gallons per square yard per day, to negligible amounts.

Factors in mist propagation

Temperature

It was thought that evaporation from the sprayed pots might lower the temperature of the medium in relation to similar pots watered once a day in an unsprayed bin. Only limited differences were detected, temperature being about 2·3° F. lower in the sprayed bin. In the shaded bin the

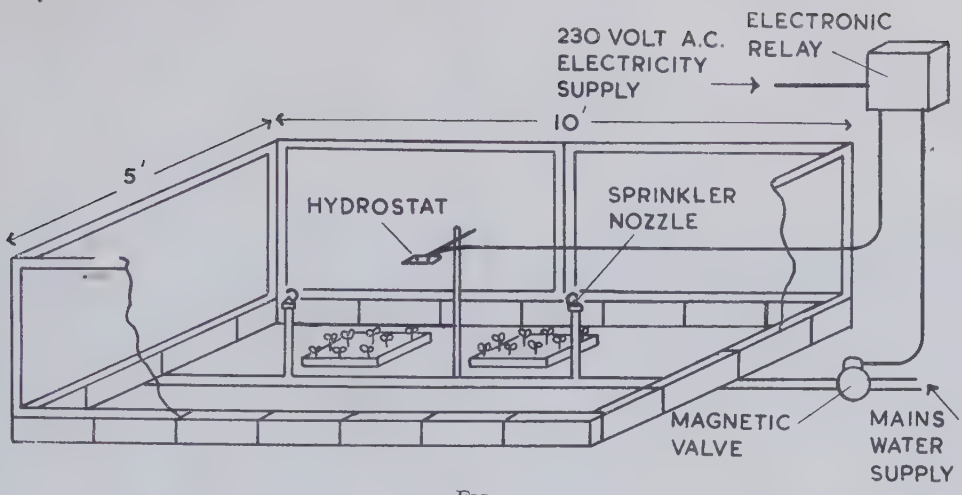

FIG. 4
Isometric drawing of single mist propagation frame

minimum temperature was in fact slightly above that in the open. Within the leaf tissues themselves the temperature, measured with thermocouples, during the day was 3–5° F. lower than that of the surrounding air, though at night the difference was very much smaller.

Light

By setting cuttings in the open frame full advantage was taken of the available daylight, but it was found that on very sunny days there was considerable scorching of the leaves ; species being scorched in varying degree. Immature soft cuttings were severely scorched, but more mature cuttings taken later in the season were less damaged in spite of increased sunshine.

Because of the dangers of scorching, the effect of shading the bins was tested. A covering of coir wind screening (coconut string matting of $\frac{2}{3}$-in. square mesh) reduced light intensity to half, and cuttings under these shaded conditions did not scorch, rooted more profitably and made more vigorous root growth than in the open (Table III).

Rooting medium

The usual rooting medium for the closed propagation case is a mixture containing equal parts of coarse sand and peat. Under mist, however, the medium remains permanently at field capacity and it was considered desirable to test if under such conditions aeration is sufficient for root formation. Softwood cuttings of an apple rootstock were therefore set in $2\frac{1}{2}$-in. fibre pots, containing media with varying proportions of sand and peat, the air and water content of which are presented in Table II. It will be seen that the water holding capacity of a 50 : 50 mixture is double that of pure sand, whereas differences in gaseous volume at field capacity are much smaller and all the mixtures are sufficiently aerated for effective rooting (Table III). In unshaded mist it was noted that the higher the proportion of peat the greener the leaves, but also the greater the amount of scorching. Best rooting was found in the 75 : 25 sand-peat mixture, suggesting that this mixture gave the best compromise between these contrary influences. By shading, the unfavourable influence is eliminated, and excellent rooting results whatever the proportion of sand and peat. But even here the presence of peat appeared to be an advantage later when the cuttings were moved from the mist for hardening.

TABLE II

CONSTITUENTS BY VOLUME OF ROOTING MEDIA UNDER MIST

Medium, sand : peat proportion	Percentages			
	Solids	Porosity	Water	Gases
50 : 50	33	67	51	16
75 : 25	44	56	38	18
100 : 0	53	47	26	21

TABLE III

ROOTING OF APPLE SOFTWOOD CUTTINGS (ROOTSTOCK 343I) IN DIFFERENT MEDIA UNDER MIST

Medium sand : peat proportion	Unshaded Mist			Shaded Mist		
	Percentage rooted	Number of roots per cutting	Length of longest root (mm.)	Percentage rooted	Number of roots per cutting	Length of longest root (mm.)
50 : 50	64	2·8	39	93	9·1	104
75 : 25	74	5·3	74	96	8·1	104
100 : 0	56	4·4	43	96	6·8	82

Transplanting

Roots formed under mist are thick and fleshy and initially without root hairs, probably because there is low moisture stress and little need for absorption. The cuttings, even though well rooted, are consequently severely damaged by scorching on sudden removal from mist. Transference of rooted cuttings to the nursery must therefore be preceded by a gradual hardening.

When all cuttings in an enclosure are at a similar stage, hardening is conveniently done by adjusting the sensitivity and position of the hydrostat to reduce the frequency of the spray. The next stage is to switch off the apparatus at night and then progressively earlier until it is completely out of action. Shaded cuttings should at the same time be gradually exposed to light. When rooted cuttings are removed from the frame they are placed under partial shade and watered at intervals according to conditions and stage of hardening. Scorching is most likely to occur in the first two or three days following removal and special care is needed during this period.

To avoid disturbance the cuttings may be rooted in small fibre pots which are transplanted intact. The roots readily penetrate the fibre walls (Fig. 5) and the pot quickly disintegrates when buried in moist soil.

Construction of the frames

The frames used in 1956 for experiments on various horticultural aspects of propagation under mist consisted of a series of bins, each 10 ft. × 5 ft., in the open air (Fig. 4). Each bin contained two nozzles held 18 in. above ground level on vertical stand pipes, spaced 5 ft. apart on a central ½-in. feed pipe connected to the mains water supply by a magnetic valve. Standard Dutch lights supported on concrete blocks formed a transparent wind shield 3 ft. high, partial shade being provided where required by coir wind screening. The earth floor of the bin was slightly sloped and covered with a layer of clinker to provide good drainage.

The nozzles were Vaspra S15 type, with specially flattened anvils, working at a water pressure of not less than 30 lb. per sq. in. A strainer fitted in the feed pipe avoided blocking, and a drainage tap at the end of the feed pipe enabled dirt to be flushed out.

The hydrostat was midway between, and 6 in. above the nozzles of the first bin, with facility for adjustment.

The rooting medium was a mixture of equal portions of coarse sand and peat, and each cutting was set in a fibre pot to minimize root disturbance at planting out. The main trials will be reported later.

Discussion

These studies on mist propagation have shown that this is a technique which can be operated in the open. A somewhat unexpected finding of the preliminary experiments was the benefit gained by partial shading of the bins, which with cuttings taken early in the growing season avoided the serious risks of scorching on a hot day. The use of Dutch lights for wind shields could therefore be modified to some less fragile and cheaper alternative. From experiments so far it would seem that the chief danger is sudden changes of environment and these are avoided by shading and by gradual hardening of the rooted cuttings before transference to the nursery.

The most important features of this set-up have been its trouble-free working throughout the season, and the maintenance of turgidity in the leaves with a minimum amount of water. There has therefore been little run-off from the leaves and no undue leaching from them. Another advantage of the limited amount of spray is that the hardness of water is not a vital matter.

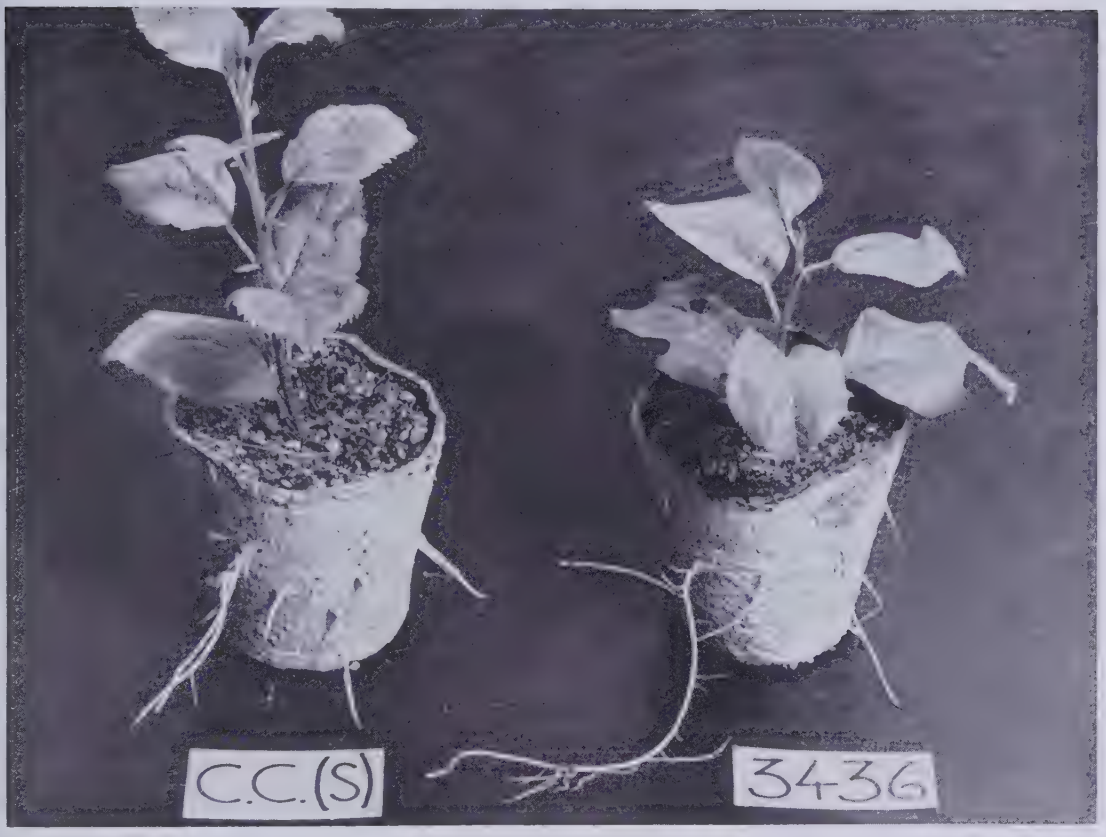

Fig. 5
Apple rootstock cuttings rooting through fibre pots

[face page 58

Acknowledgements

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Summary

The development and installation of hydrostatically controlled mist propagation frames for use outdoors are described. Partial shading of the frames greatly benefits rooting, by preventing scorching. Equal parts of coarse sand and peat is a suitable medium for propagation under mist. Rooted cuttings must be gradually hardened off before transference to the nursery.

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Appendix

Components and their suppliers for mist propagation frame installation.

1. Vaspra nozzles with flattened anvils : Messrs. Vaspra Ltd., 15 Philpot Lane, London, E.C.3.
2. Magnetic valve, Model NXTIE/1 : Teddington Industrial Equipment Ltd., Sunbury-on-Thames, Middlesex.
3. The electronic relay can be made from standard radio parts, as specified in Fig. 3, by a radio engineer.
4. Strainer for feed pipe : Messrs. W. Weeks & Son, High Street, Maidstone, Kent.

ROOTSTOCK EFFECT ON THE REGENERATION OF APPLE CUTTINGS

By R. J. GARNER and E. S. J. HATCHER*

It has long been realized that the origin or source of a cutting affects its rooting. Cuttings from plants grown in hedges root well, and hedge culture is now recommended for providing cuttings (Garner and Hatcher, 1955). As different rootstocks are known to have large effects on growth, cropping, and other characters of the scion, it was decided to test whether hedges formed of trees grafted on different rootstocks would produce shoots that would behave differently as cuttings.

Materials and methods

The shy rooting, very vigorous, apple rootstock Malling Crab C (Garner, 1946) was budded in 1948 on to itself and also on to the four rootstocks, M.IX, M.VII, M.II and M.XVI, representatives respectively of dwarfing, semi-dwarfing, vigorous and very vigorous groups of rootstocks (Hatton, 1935). In addition, some Crab C rootstocks were left unbudded, making six source types altogether. The resulting maiden trees were shortened to 18 inches above ground and left in the nursery for a further year, after which they were transplanted 18 inches apart in a single row to form a permanent hedge. This row was composed of two randomized blocks containing source units of ten trees, so that twenty trees of each of the six types were planted. Vigorous erect shoots were cut back to 8 inches and all others kept below the level of these by less severe tipping, and in subsequent years vigorous shoots were shortened to some 4 inches from their base.

In early November, 1953, when the hedge had been established for three years, and the trees were five years old, the first batch of cuttings was obtained by collecting 100 shoots from each of the twelve sections of hedge. One 12-inch cutting was made from the base of each shoot and cuttings of like origin were amalgamated and dealt into two lots, one of which was given an instantaneous alcoholic dip containing $2\frac{1}{2}$ mg. indole-3-butyric acid (IBA) per millilitre (Hatcher and Garner, 1951). All cuttings were placed in peat-sand medium in storage bins surrounded and covered with straw to conserve warmth. They were taken from store and planted in open ground in the following March. Records were taken of the condition of the cuttings on removal from storage, a census of planted cuttings was taken in early summer, and final records of establishment were secured the following winter.

The experiment was repeated in 1954–55, but the cuttings were then stored in electrically heated bins with a minimum temperature of 45° F. at their bases 8 inches below the surface of the peat-sand medium (Garner and Hatcher, 1957 ; Hatcher and Garner, 1957). In 1955–56 two concentrations of growth-substance treatments were applied : half the cuttings received an IBA dip of 1 mg. per ml. and the other half $2\frac{1}{2}$ mg. per ml. alcoholic solution. In this latter year the cuttings were stored at 55° F. for four weeks and then in straw protected storage for the rest of the winter.

In the first year the cuttings were planted in eight, and in subsequent years six, replicated blocks each containing the twelve treatments in random order.

Results

Condition of cuttings after storage

The cuttings were removed from storage in spring whilst their buds were still dormant, although there was considerable activity at the bases of the cuttings. Those receiving no growth substance treatment (in the 1953–54, 1954–55 experiments) had developed a moderate amount of callus, with an occasional root ; but callusing and rooting were much more advanced in the IBA-treated cuttings. Behaviour in relation to sources was generally consistent over the three seasons, cuttings from shoots on the more vigorous rootstocks having most roots. The order of root development of cuttings previously treated with growth substance is shown in Table I.

Condition of cuttings in early summer

At the end of May in each year, when shoot growth had begun, each cutting was examined and recorded. Again, the cuttings treated with growth substance were far more advanced than the others. In the first experiment less than 3 per cent of the non-treated cuttings were growing compared with

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TABLE I

RELATIVE ROOT DEVELOPMENT AT PLANTING, AFTER STORAGE, OF CRAB C HARDWOOD CUTTINGS FROM HEDGE PLANTS ON VARIOUS ROOTSTOCKS (INCREASING ROOTING FROM LEFT TO RIGHT)

Season	Rootstock order					
1953–54	IX	II	VII	Crab C	XVI	Own roots
1954–55	IX	II	Crab C	VII	XVI	Own roots
1955–56	IX	VII	II	Own roots	XVI	Crab C

32 per cent of the treated ; in the second experiment the values were nil and 36 per cent respectively. In the final experiment, however, in which all cuttings received treatment, only about 10 per cent had made extension growth by the end of May and, as will be seen in Table II, rootstock effect could not at this stage be sharply distinguished. In May, 1954 and 1955, growth was far more advanced, and cuttings from hedges on the more vigorous root systems were superior to those grown on the dwarfing or semi-dwarfing stocks.

TABLE II

CONDITION IN THE CUTTING BED AT END OF MAY. PERCENTAGE OF CUTTINGS GROWING (ALL TREATED WITH GROWTH SUBSTANCE THE PREVIOUS AUTUMN)

Season	Rootstock					
	M.IX	M.VII	M.II	Crab C	Own roots	M.XVI
1953–54	9	31	27	34	39	51
1954–55	30	23	35	40	37	53
1955–56	5	10	13	14	8	13
3-Year Mean	14·6	21·3	25·0	29·3	28·0	39·0

Establishment of cuttings

The final establishment (percentage grown) was much lower in the third experiment, but behaviour was similar throughout. In the absence of stimulation by growth substance few cuttings rooted (4 per cent) and differences between rootstocks were not statistically significant. When growth substance was used, however, final establishment figures depended on rootstock, treatment effects being highly significant ($P<0.001$). Cuttings from hedges on M.IX gave the lowest, and on M.XVI the highest, establishment (Table III), the mean percentages for these extremes being 22·3 and 54·3. The overall ascending order of establishment in relation to rootstock used was M.IX, M.VII, M.II, Crab C, M.XVI, with some variation in individual experiments.

TABLE III

FINAL ESTABLISHMENT OF CUTTINGS TREATED WITH GROWTH SUBSTANCE (PERCENTAGES)

Season	Rootstock					
	M.IX	M.VII	M.II	Crab C	Own roots	M.XVI
1953–54	21	37	35	40	56	58
1954–55	33	33	48	43	53	67
1955–56	13	15	28	20	23	38
3-Year Mean	22·3	28·3	37·0	34·3	44·0	54·3

Figures bracketed do not differ significantly at $P=0.05$.

In the 1955–56 experiment treatment with growth substance at the lower concentration gave better establishment than the heavy dip normally used for apple cuttings, and these better values have been used in Table III. The implication is that the more concentrated treatment in conjunction with the higher initial storage temperature (55° F. for four weeks) led to over-sensitization of the cuttings, an important question which is discussed in another paper (Hatcher and Garner, 1957).

Discussion

It is not surprising to find that rootstocks, which so widely influence scion performance, should also modify the quality of shoots and so affect their rooting. From the data presented, it is clear that vigour-inducing root systems give rise to improved rooting of scion shoots, when compared with dwarfing root systems.

So far, two characteristics of trees on dwarfing rootstocks have been seen in the hedges. One is the reduction in shoot growth, notably in trees on M.IX, leading to a delay in the full development of a typical hedge form ; and the other is the prevalence of flowering in the hedges on M.IX, and to a lesser extent in those on M.II and M.VII. Propagators generally regard the conditions accompanying flowering as inimical to ready rooting.

Within the very vigorous graft combinations also, rootstock influence was discernible, for in all three experiments Crab C on M.XVI was superior to Crab C grafted on itself. This was somewhat unexpected, for observations on trees of various apple varieties grown for some twenty-five years on these two stocks have revealed similarity of vigour (Garner, 1946). There is also some indication that non-grafted Crab C may yield better cuttings than Crab C grafted upon itself. These features call for further observation.

The fact that it is possible, by the use of rootstocks, to improve the performance of hedges as sources of cuttings, suggests that there may be some practical advantage in forming hedges of grafted material. If this is done, care will be necessary to use healthy material and to eliminate any sucker shoots which may arise from the rootstocks before the collection of cuttings ; though no suckering has yet occurred in the hedges in the present experiments.

Summary

Hedges of Malling Crab C apple rootstock on its own roots, grafted on itself and upon rootstocks of differing vigour were used as sources of hardwood cuttings in three consecutive years. Cuttings from hedge plants on vigorous rootstocks established better than those from hedges on dwarfing stocks. It is suggested that parent plants may be improved as sources of cuttings by grafting upon selected rootstocks.

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OBSERVATIONS ON *PRUNUS CERASUS, P. MAHALEB* AND OTHER SPECIES AS ROOTSTOCKS FOR SWEET CHERRIES

By R. J. GARNER and CATHERINE P. NICOLL

Almost all cherry trees in Great Britain are grown upon sweet cherry (*P. avium*) rootstocks. It is only the acid cherries (*P. cerasus*), notably the Morello, which have occasionally been worked on other species such as *P. mahaleb* or to an even lesser extent on the acid cherry itself.

It is doubtful if reduced vigour is of any advantage in an acid cherry, for in these, fruiting is dependent upon a plentiful supply of young wood. Sweet cherries, on *P. avium* rootstocks invariably grow into large trees carrying much of their fruit on older wood, so that in this group some curtailment of vigour would be useful both for commercial (Garner, 1955), and garden use. The desire to restrict tree size in sweet cherries has led to enquiries for rootstocks of less vigour, so that trees might be planted more closely than at present and picked from shorter ladders. Real dwarf trees of sweet cherry would, however, be welcome in the garden.

In recent years there have been considerable plantings of sweet cherry in bush form (i.e. with short trunks) in the hope of simplifying spraying and picking. These trees, on commercially available sweet cherry rootstocks, have grown vigorously and require as much space as the traditional standard cherries. The true bush tree of restricted growth must await the production of less vigorous rootstocks.

If suitable *P. avium* rootstocks of less vigour were available, they would probably satisfy the needs of commercial cherry growers, but meanwhile related species of cherry are being tested, many of which grow less vigorously than the sweet cherry. Some of these have been tried in a number of countries, the ' Kentish ' in Australia, the ' Stockton Morello ' in California (both *P. cerasus*), and the ' Mahaleb ' (*P. mahaleb*) in America, Australia and Europe. Reports have often been far from favourable, but specimens of rootstocks of these and other species have been collected, vegetatively propagated, and worked with scion varieties of sweet cherry. Whilst the performance of much of this rootstock material has been unsatisfactory under conditions at East Malling, it is desirable that the observations should be placed on record.

Nursery observations

Acid cherries (*P. cerasus*)

Most of the acid rootstocks tested were received from overseas, others were either collected in Kent or raised at East Malling from seed (Table I).

In general, acid cherry stocks root quite readily when layered by the etiolation method (Garner, 1944) and they can also be raised by root cuttings from young nursery trees, but the Stockton Morello, normally raised from suckers in California, has rooted rather less readily from layers than the others.

TABLE I

ACID CHERRY ROOTSTOCKS RECEIVED

Year received	East Malling Index No.	Name	Origin	Nature
1922	F 18/5	Wild Acid	Folkestone, Kent	Seed
1924	F 100	Wye Morello	Harrietsham, Kent	Suckers
1931	F 235	Stockton Morello	California	Suckers
1931	F 250	Kentish	Australia	Raised from root cuttings
1939	F 350	Leitzkauer Pressauerkirsche	Germany	Layers
1947	F 442	Kentish	Australia	Raised from root cuttings
1948	F 476	Westerlee Morello	Holland	Suckers

The ' take ' of sweet cherry buds on these acid rootstocks has usually been very low compared with the same scion varieties on a sweet cherry rootstock (Table II), though the scion variety Frogmore Early gave much better stands than others.

Table II

Acid cherry rootstocks in the nursery. Numbers budded and percentage maidens produced

Scion Variety	Rootstocks											
	Kentish (F250)		Leitzkauer (F350)		Stockton Morello (F235)		Wye Morello (F100)		Dwarf Acid (F18/5)		F12/1 *P. avium*	
	No. budded	% Maidens	No. budded	% Maidens	No. budded	% Maidens	No. budded	% Maidens	No. budded	% Maidens	No. budded	% Maidens
Early Rivers	19	26	—	—	22	4	27	0	21	0	16	81
Frogmore Early ..	18	50	32	81	43	60	37	70	47	59	33	91
Kent Bigarreau ..	11	45	—	—	—	—	25	12	14	0	15	100
Napoleon	6	50	32	28	—	—	10	0	29	14	6	50
Noble	6	33	30	7	—	—	11	0	30	0	6	100
Noir de Guben ..	6	0	32	28	—	—	9	0	29	0	5	100
Roundel	12	0	—	—	—	—	22	0	15	0	25	88
Waterloo	6	50	31	58	18	0	9	0	27	4	6	50

Mahaleb cherries (*P. mahaleb*)

Seedling mahaleb are commonly used in various parts of the world, often with unsatisfactory results. When worked with sweet cherry scions they show incompatibility, being variable in growth and short lived (Anthony *et al.*, 1937 ; Quinn, 1935). Selected seedlings of mahaleb, propagated vegetatively, were tried at East Malling as rootstocks for Morello (Grubb, 1933) and for Kentish Red (Grubb, 1940). The young trees grew vigorously at first, but after a few years became stunted and bore smaller fruit than comparable trees on sweet cherry rootstocks. Three sweet cherries, Early Rivers, Governor Wood and Waterloo, worked on three selected vegetatively propagated mahaleb all proved highly incompatible in the nursery (Grubb, 1940).

Unlike acid cherries, the mahaleb roots very poorly when layered. Both hardwood and root cuttings have failed to root and established trees do not sucker from their roots. However, all mahalebs tried have rooted extremely well from softwood cuttings, but such rooted cuttings need a further year in the nursery before they are fit to line out for budding.

As with acid cherry rootstocks, the nursery behaviour of mahaleb rootstocks has been unsatisfactory. Bud takes have been poor but the few resulting trees have grown vigorously in the nursery.

In spring, 1954, a nursery trial of mahaleb rootstocks of different origin was planted with one sweet cherry (F12/1) and one acid cherry (Kentish) rootstock as controls. One of the mahalebs, found in France by Dr. A. B. Beakbane, came with a reputation for compatibility with sweet cherries, two others were collected in New Zealand by Mr. T. Neame, another had been selected and propagated at East Malling. These four were multiplied vegetatively, but some mahaleb raised from seed received from Oregon, were also included in the trial. The four vegetatively propagated mahalebs were raised by softwood cuttings and were very small when planted, and fewer of these were fit to bud than of either the seedlings or the sweet and acid rootstock controls raised by layering. Once successfully budded the young trees grew well. The scion varieties were Early Rivers and Merton Heart. The order of vigour in the maiden year, as shown by height, was fairly consistent in both varieties, the outstanding feature being the vigorous growth of trees on the mahaleb selected at East Malling and the low vigour of those on one of the mahalebs (F552) collected in New Zealand. The trial was maintained in the nursery a second year when note was taken of survival of trees and length of new shoots.

Both scion varieties survived equally well, but highly significant differences between rootstocks were found. The two controls, F12/1 and Kentish, achieved almost complete success, but survival of trees on all the mahalebs was unsatisfactory, with the New Zealand stocks and the East Malling selection least successful.

The order of vigour of the rootstocks was not affected by vigour of scion variety, although Early Rivers made much larger trees than Merton Heart. The rootstocks are arranged in descending order of vigour in Table III. The two used as controls are distinctly different in vigour, F12/1 inducing strong growth and Kentish giving rise to much smaller trees. The range of the mahalebs is much wider. Well above F12/1 there is a very vigorous group composed of the French, East Malling and seedling mahalebs ; one of those from New Zealand (F551) falls between the controls whilst the other (F552) is the weakest of all.

Vigour range in the nursery, however, is not a reliable indication of later behaviour and though F552 appears promising as a dwarfing rootstock final judgement must await plantation tests.

TABLE III

MAHALEB ROOTSTOCKS IN THE NURSERY.
TOTAL GROWTH OF SHOOTS PER TREE IN THE SECOND YEAR (CM.)

Rootstocks	Early Rivers	Merton Heart	Totals
French Mahaleb	961	657	1,618
East Malling Mahaleb	928	650	1,578
Seedling Mahaleb	847	731	1,578
F 12/1 (*P. avium*)	791	543	1,334
Mahaleb F 551 (N.Z.)	768	523	1,291
Kentish F 442 (*P. cerasus*)	660	328	988
Mahaleb F 552 (N.Z.)	461	328	789

Other species

In addition to *P. cerasus* and *P. mahaleb* already mentioned, other species were tried as possible rootstocks. These species were chosen primarily for their dwarf characteristics, but some attention

Table IV

The nursery behaviour of various species

Name	Method of propagation	Percentage rooting of cuttings	Compatibility in the nursery with sweet cherry scions								
			Early Rivers			Napoleon			Frogmore Early		
			No. budded	Maidens	2 year	No. budded	Maidens	2 year	No. budded	Maidens	2 year
P. besseyi	Seedlings	—	12	1	0	—	—	—	12	0	—
P. canescens	Softwood cuttings	60	4	2	2	4	1	1	—	—	—
P. glandulosa albo-plena ..	,, ,,	90	5	3	0	5	3	0	—	—	—
P. japonica nakai ..	,, ,,	90	3	0	—	3	1	0	—	—	—
P. laurocerasus caucasica ..	—	—	—	—	—	—	—	—	3	1	0
P. maddenia hypoleuca	Softwood cuttings	55	4	0	—	6	0	—	—	—	—
P. mugus	,, ,,	55	3	3	3	3	3	3	—	—	—
P. padus	Layers	—	9	1	0	—	—	—	15	8	0
P. pseudocerasus ..	Softwood cuttings	85	2	0	—	3	0	—	7	6	2
P. serrulata	Layers	—	—	—	—	—	—	—	13	11	4
P. wadai	Softwood cuttings	100	4	1	1	5	2	2	—	—	—
P. avium (F12/1) ..	Layers	—	5	5	5	6	4	4	4	4	4

was paid to indications of ease of propagation, such as the presence of burr-knots at branch junctions. Such plants were multiplied in various ways, but mainly by softwood cuttings, and there was little difficulty in obtaining small quantities for preliminary trials. Small numbers of rootstocks were lined out in the nursery and worked with scion varieties of sweet cherries alongside a sweet cherry rootstock (F12/1) as control.

In general, takes were low and some of the maiden trees failed to survive a second year (Table IV). Of the ten species tried, only half retained their scions for two seasons and it is doubtful if any, except *P. mugus* and possibly *P. canescens*, deserve further trial.

In 1952 sufficient material of *P. wadai* was available to plant a nursery trial for budding with two sweet varieties, Early Rivers and Merton Heart and with Morello. The rootstocks transplanted and grew well, there was a satisfactory production of trees which grew very vigorously for two years, but by the end of the third year many of the trees were dead. Such trees were found to have rotted at ground level, but though this condition resembled that caused by *Phytophthora* spp., no known pathogenic fungus was isolated. Even the trees on *P. wadai* which were alive at the end of three years were not entirely healthy ; there were dead areas below some of the unions and in all cases numerous suckers had developed at ground level, and these may have helped to keep the trees alive. The behaviour of the trees is summarized and compared with that on *P. avium* (F12/1) and *P. cerasus* (Kentish) in the same trial, in Table V.

TABLE V

THE BEHAVIOUR OF TREES ON *P. wadai* IN THE NURSERY.
MAIDENS PRODUCED, THEIR GROWTH, AND SURVIVAL AT THE END OF THREE YEARS

Rootstock	Scion	No. budded	Percentage maidens produced	Height of maidens (cm. per tree)	Percentage trees alive at 3 years
P. wadai	Early Rivers	14	64	171	44
	Merton Heart	14	50	128	43
	Morello	13	54	144	43
P. avium (F 12/1) ..	Early Rivers	14	85	156	100
	Merton Heart	14	85	139	100
	Morello	13	100	129	100
P. cerasus (Kentish) (F 442)	Early Rivers	12	50	147	83
	Merton Heart	10	90	146	89
	Morello	13	77	117	90

Performance in the plantation

Acid cherries (*P. cerasus*)

In December, 1943, a small trial of sweet cherries on five acid rootstocks was planted to obtain preliminary information on the possible use of such combinations for bush trees. At planting, notes were taken of the nature of the root systems and of swellings at the union (Table VI).

The five acid rootstocks in this first planting have fallen into two distinct groups in regard to growth as shown by length of new wood produced and height and spread of the head of the tree (Table VII). Cropping also, over a five-year period, falls into the same two groups, being heavier on the larger trees. By 1949, when the trees had been planted five years, those on the acid rootstock Leitzkauer had made considerably more growth, as shown by new shoots and size of head, than the control trees on *P. avium* F12/1.

Trees on Wye Morello had made nearly as much shoot growth as trees on F12/1 and were somewhat larger ; both on Leitzkauer and Wye Morello cropping was considerably heavier than on F12/1. From 1949 until the trial ended in 1953 new shoot production on the two acid rootstocks fell to 12 and 21 metres respectively, whilst that on F12/1 was greatly increased to 32 metres over the three-year period.

In the final year of the trial brief notes were taken of the state of the trees, particularly in regard to anchorage and general health. Most of the trees on acid rootstocks were very poorly anchored, only two, both on Wye Morello, being moderately well anchored. In contrast the trees on F12/1 were very firm in the ground. Of the 21 trees remaining in the trial only seven were deemed to be in a satisfactory condition in regard to general health, irrespective of anchorage. Of these, 3 were on Wye Morello, 2 on Leitzkauer and 3 on F12/1 ; the 3 other trees on F12/1 were marked down because they were damaged by Bacterial Canker.

Table VI

Acid cherry rootstocks in the plantation.
Root and union characteristics at planting, and survival of trees

Scion variety	Rootstock	No. of trees planted	Age of trees	Nature of root systems at planting	Swelling above the union	Trees alive at end of 5 years	Trees alive at end of 9 years
Frogmore Early ..	Dwarf acid (F18/5)	6	2 years	Main roots from base of system. Almost no fibre	Considerable	4	0
	Wye Morello (F100)	6	,,	Long horizontal roots moderately fibred	Slight	6	6
	Stockton Morello (F235)	6	,,	Similar to Kentish, but fewer coarse roots	Considerable	5	1
	Kentish (F250)	3	,,	Mainly basal. Moderate fibre. No collar fibre	Very slight	3	2
	Leitzkauer (F350)	5	1 year	Compact root system. Abundantly fibred	Slight	5	4
	F12/1 *P. avium*	6	2 years	Strong root system, abundant fibre. Some collar fibre	None	6	6
Early Rivers.. ..	Kentish (F250)	3	,,	Mainly basal. Moderate fibre. No collar fibre. Less restricted system than under Frogmore Early	None	3	2

Table VII

Acid cherry rootstocks in the plantation.
Growth and cropping, first 5 years from planting. Scion variety Frogmore Early

Rootstock	Total shoot growth per tree (cm.)	Height and spread of head of the tree (metres)		Accumulated crop (lb.)
		Height	Spread	
Dwarf Acid (F18/5)	1,317	1·1	0·9	5·3
Stockton Morello (F235) ..	1,414	1·1	1·0	7·6
Kentish (F250)	1,345	1·2	1·0	3·9
Wye Morello (F100)	4,069	1·7	1·6	14·4
Leitzkauer (F350)	5,807	1·9	1·8	12·7
F12/1 (*P. avium*)	4,202	1·6	1·4	9·9

Concurrently with the above trial 12 trees of Frogmore Early were planted for a pruning trial, half being on the acid rootstock Leitzkauer and half on the sweet rootstock F12/1. The pruning treatments were normal tree shaping and branch thinning compared with light tipping of the longest leaders. These treatments did not greatly differ in their effects on the trees.

The trees were not staked at planting time in December, 1943. In early October, 1946, there were severe gales and some of the trees were blown over to a maximum of 45° from the vertical, others were rocked and loosened in the soil. All the trees moved were on Leitzkauer, two trees, one protected by adjacent trees and another with a small head, were not affected. The trees on F12/1 were not damaged.

Girth measurements were taken annually 9 in. above and 1½ in. below the union and these, shown as area of cross section, are summarized in Table VIII. The F12/1 below the union is considerably larger than the Frogmore trunk above it, but in the trees on Leitzkauer the trunk is very much smaller below the union than above. This has been the experience with all the trees of sweet cherry on acid rootstocks at East Malling.

In 1948, the fifth year from planting, root suckers were observed beneath five of the trees on Leitzkauer. These varied from 1 to 24 per tree. All suckers were thereafter removed in the season of their appearance, but more appeared and by 1950 all trees on Leitzkauer had suckered and in that year one sucker also appeared from one of the trees on F12/1.

Table VIII

Frogmore Early on an acid and a sweet cherry rootstock.
Conformation of the trunk at the union (means per tree)

Rootstock	No. of trees	Area of cross-section of trunk (sq. cm.)			
		At end of 5 years		At end of 10 years	
		9 in. above union	1½ in. below union	9 in. above union	1½ in. below union
Leitzkauer	5	88	59	311	186
F12/1	6	111	164	385	522

Yields in 1948 averaged 3 lb. of fruit per tree, and at this time the fruit from the trees on Leitzkauer tended to be slightly larger ; in later years fruit size, though variable from tree to tree, was not correlated with rootstock. At ten years from planting the trees on F12/1 had carried a total crop of 190 lb. compared with 153 lb. per tree on Leitzkauer. At this time the former trees were rather taller but of similar spread to the latter (Table IX). All the trees were then grubbed and the trunk and branches weighed. The trees on Leitzkauer had a mean weight of 104 lb. and those on F12/1 141 lb., a larger difference than shown by height and spread (Table IX).

TABLE IX

FROGMORE EARLY ON AN ACID AND A SWEET CHERRY ROOTSTOCK
SIZE OF TREE AND CROP AT 5 YEARS AND AT 10 YEARS (MEANS PER TREE)

Rootstock	No. of trees	At end of 5 years				At end of 10 years			
		Height of tree (metres)	Spread of tree (metres)	Total crop (lb.)	No. of fruits per lb.	Height of tree (metres)	Spread of tree (metres)	Total crop (lb.)	No. of fruits per lb.
Leitzkauer (F350)	5	1·8	1·7	3·1	96	3·5	4·3	150	114
F12/1	6	2·3	2·0	3·2	112	4·1	4·6	187	111

In March, 1949, a third observation trial was planted with three-year-old trees of five sweet cherry varieties on four acid rootstocks with *P. avium* F12/1 as control. A few trees on *P. mahaleb* and *P. serrulata* were also planted and will be discussed later. The trees behaved much as in the previous trials, some failed to survive, some developed suckers from the roots, and trees on acid rootstocks were weakly anchored. The trial was planted adjacent to a large block of established cherries, which were later removed, and this probably accounted for severe depredations by birds on this small isolated plot, resulting in loss of yield records.

The only complete set of trees available was of the scion variety Frogmore Early. Smaller units of the varieties Napoleon, Waterloo, Noir de Guben and Noble were planted, but the first two suffered severely from Bacterial Canker and the others were planted in units of not more than three of any one combination.

Frogmore Early was planted on the full range of rootstocks and with this variety all trees on acid rootstocks survived for eight years, when the trial ended (Table X).

TABLE X

ACID CHERRY ROOTSTOCKS IN THE PLANTATION. ANCHORAGE AND SUCKERING (UNITS OF FOUR TREES). SCION VARIETY FROGMORE EARLY

Rootstock	Anchorage at 8 years			Suckering at 4 years		
	Firm	Loose	Very loose or leaning	No. of trees with suckers	Total no. of suckers	Total length (cm.)
Dwarf acid (F18/5)	0	0	4	1	3	80
Wye Morello (F100)	1	2	1	3	18	1,327
Stockton Morello (F235) ..	0	3	1	3	7	463
Kentish (F250)	0	1	3	2	11	589
Leitzkauer (F350)	1	3	0	3	12	711
F12/1 *P. avium*	4	0	0	0	0	0

In 1956 a record was taken of the condition of the fruit spurs on three- and four-year-old wood in some eight-year-old trees of Early Rivers on two acid rootstocks, Dwarf Acid and Stockton Morello, and on the sweet cherry rootstock, F5/4. The three-year wood in the trees on Stockton Morello had a larger proportion of dead spurs than in either of the others, whilst on the four-year wood Stockton Morello and Dwarf Acid had 32·9 and 30·7 per cent respectively, compared with 10·8 per cent on F5/4. The differences between the first two and F5/4 are highly significant ($P. < 0.001$).

Mahaleb cherries (*P. mahaleb*)

As mentioned earlier, the bud-take of sweet cherry varieties on mahaleb rootstocks at East Malling has been very poor, consequently few trees have reached the plantation. Of seven trees planted in March, 1949, only two remained alive in 1956. All the trees grew vigorously for a few years and remained firmly anchored until dead, there has been no restriction of girth below the union, and no suckering has occurred. A single selected mahaleb, vegetatively propagated, was used and it is possible that other selections might behave differently, but as Howe (1927) found, even seedling mahaleb has been unsatisfactory when worked with sweet cherries in the State of New York.

Other species

The only sweet cherries on other species to reach the plantation were four trees of Frogmore Early and two of Waterloo on a selection of *P. serrulata*. These were planted as three-year-olds in March, 1949. One of the Frogmore trees died in 1951 and another in 1956. The remaining four trees made little growth, but remained firmly anchored and did not sucker.

Trees from Australia

The unsatisfactory behaviour of trees raised at East Malling gave rise to doubts as to the nature of the material and to check this, a consignment of trees raised in Australia was imported in the spring of 1947. There were 24 trees of five varieties of sweet cherry, all worked on the acid rootstock Kentish, and also 50 Kentish unworked rootstocks. The material had left Melbourne towards the end of April in the Australian autumn and was planted at East Malling on 20th May, 1947, some five weeks from lifting in Australia and without having passed through a winter, except for the period in cool stowage on board ship. The unworked rootstocks (*P. cerasus*) leafed out immediately and grew normally, but the worked trees remained quite dormant until the spring of the following year, except that a few small sucker shoots grew from below the graft unions of some of the trees. The trees grew normally following their first winter in England.

The Australian trees behaved similarly to those raised at East Malling. Anchorage was either loose or very loose, the rootstock stem below the union was somewhat restricted and there was considerable suckering. Similar behaviour in Australia had been reported by Quinn (1935).

Discussion

Many cherry species are less vigorous than the sweet cherry, notably the acid cherries of various kinds and also numerous shrubby species, and investigators have used a number of these as rootstocks for sweet cherry. The mahaleb has also been tried largely because it has exercised a restrictive effect on growth of acid varieties. However, sweet varieties on Wye Morello, for example, grow as vigorously as they do on a sweet cherry rootstock, and on mahaleb the sweet scions grow extremely vigorously, at least for a few years. Even the shrub-like *P. wadai* has induced great vigour in scions worked upon it. On the other hand some rootstock selections such as the Dwarf Acid, Stockton Morello and a selection of *P. serrulata* have given rise to small weakly growing or stunted trees. Throughout the cherry rootstock trials at East Malling any considerable reduction in vigour has been associated with signs of ill health.

Judging by the species examined there would be little difficulty in propagating any cherry species vegetatively, if it were found to be of value.

In numerous nursery trials there have been poor stands on all species tried, except *P. avium*, but the limited numbers of trees obtained have often made strong growth initially. Growth on mahaleb rootstocks has often been excessive for some years, but such trees have then died ; it seems that such excessive vigour may be an early symptom of incompatibility.

Two other characters in which sweet cherry (*P. avium*) rootstocks excel are firm anchorage and absence of suckering. The mahalebs are also well anchored and do not sucker from their roots and, in these respects at least, they are satisfactory. This cannot be said for *P. cerasus* and some other species which are not only weakly anchored, necessitating permanent stakes, but often sucker profusely.

The limited records available show that the cropping of trees on various species has not exceeded the cropping of the same varieties on a sweet cherry rootstock within the first ten years, a period in which rootstocks of dwarfing effect should be at an advantage.

From these observations at East Malling it is clear that none of the rootstocks of species other than *P. avium* which have reached the plantation are likely to be of value either commercially or in the garden. One or two selections now under test in the nursery may prove worthy of further trial, but from what has been seen already this possibility seems remote.

The need for compatible rootstocks which will induce moderate growth of sweet cherry scions remains.

Summary

Rootstocks of various species of cherry were collected, vegetatively propagated and tested for compatibility with sweet cherry scions. The behaviour of trees was observed over periods of up to ten years in the plantation. Trees on *P. cerasus* and some other species suckered from their roots, all were poorly anchored and a number died. Generally, trees on *P. mahaleb* grew vigorously but failed to survive. One selected mahaleb gave small trees in the nursery.

Sweet cherry (*P. avium*) varieties cropped no better on other species than on sweet cherry rootstock controls and it is considered that none of the rootstocks tested is suited to the production of sweet cherry trees of limited growth.

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FERTILE BLACK CURRANT-GOOSEBERRY HYBRIDS

By R. L. KNIGHT and ELIZABETH KEEP

Spinefree and other gooseberry varieties bred by Hunter (1950, 1955) from crosses of gooseberry with *Ribes oxyacanthoides* are not entirely free from spines and their fruit is too small for the English market. Hunter's material is being further crossed with large-fruited English types at this Station, but as a second line of attack use is being made of the spinelessness of the black currant.

Hybrids between the black currant and gooseberry have been known for nearly a century. They are spineless and sterile and should not be confused with the Worcesterberry. This, though often considered to be a black currant-gooseberry hybrid, is shown by its fertility and thorns to be of other parentage : Nilsson (personal communication) considers it to be a hybrid of *Ribes divaricatum* with *R. niveum*.

In order to attempt the transfer of spinelessness from the black currant to the gooseberry it was essential to obtain fertility in such a hybrid as a first step. This paper discusses the results to date.

Previous work

The earliest reference to hybrids of the black currant and gooseberry appears to be that of Culverwell (1883). Since then numerous black currant-gooseberry hybrids have been recorded (Palmer, 1922 ; Kuz'min, 1941 ; Nilsson, 1944), and some of these have borne parthenocarpic fruit (Duka, 1940 ; Gorskov, 1940). In addition, there is one record of occasional seeds having been set by such hybrids (Kuz'min, 1941). Nilsson (1944) attempted to backcross the hybrid without success. Colchicine treatment of cuttings carried out over several years (Nilsson, 1949, 1951, 1953) yielded one polyploid branch which produced black fruits intermediate in size between those of the parents.

Material and methods

In 1930 H. M. Tydeman pollinated 40 flowers of Baldwin black currant using pollen of the gooseberry variety, Broom Girl ; he obtained 27 fruits which yielded 874 seeds and these gave rise to 57 seedlings all of which were spineless and sterile. The best of these seedlings (B20/1) has now been maintained clonally for 25 years. In 1955, for the first time on record, B20/1 set a single open-pollinated seed and this gave rise to a weak plant which, from its appearance and from the smell of its leaves, is a black currant backcross. In the same year a large number of B20/1 flowers were pollinated with either gooseberry or black currant pollen : no seeds set.

In 1953 Tydeman crossed Boskoop black currant with Green Ocean gooseberry. The resulting seed was sown in autumn, 1953. It was taken over by the writers in the following spring under the serial number B21.

Since the sterility of these diploid hybrids is probably caused by wide differences between the parental black currant and gooseberry chromosome sets, it was decided to attempt to make them fertile by doubling their chromosome complement.

In 1954 no success was obtained from treatment of B20/1 with aqueous colchicine solutions of strengths up to 0·6 per cent. Thirty-four seedlings of B21, all with several rough leaves, were treated for 4 days using 3 or 4 drops of 0·1 per cent colchicine per day. As no effect was apparent from the use of a solution of this strength, 0·6 per cent colchicine was applied for a further 7 days using cotton wool placed around the growing point and kept continually damp with the narcotic. All the seedlings survived this treatment and all showed distorted growth a week later. Fifteen of them survived the winter and six were retained as being probably polyploid or mixoploid, judged solely on appearance.

Of these six plants, two (numbers B21/1 and B21/17) flowered in 1956 and proved fertile. B21/1 gave three self-bred fruits containing a total of nine seeds. When it was pollinated by the gooseberry variety Whinham's Industry, ten fruits containing nine seeds were set, and the reciprocal cross gave six fruits containing 41 seeds. Crosses were also made using pollen from a branch of the gooseberry variety Lancer which had been treated with colchicine and which, from its appearance and from the variation in size of its pollen, was judged to be mixoploid ; five fruits were set from which four seeds were obtained.

In an attempt to transfer genes controlling fruit size from the gooseberry to the black currant, crosses were made using two tetraploid black currants, B5/6 and B5/7. The cross B5/6 × B21/1 failed, but B5/7 × B21/17 gave five fruits containing four seeds.

Discussion

One of the colchicine-treated plants, B21/1, is illustrated in Fig. 1. The fruit of this hybrid is intermediate in size between that of the parents, being about half an inch long, and is dark red when ripe. Nothing is yet known as to the cropping capacity of such plants, but it is not expected that they will be of direct commercial value. They were bred solely as a first essential step in a planned transference of spinelessness to the gooseberry by backcrossing.

Summary

The production of fertile black currant-gooseberry hybrids and their successful backcrossing to both the gooseberry and to tetraploid black currant are described.

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Fig. 1
Branch of colchicine-treated blackcurrant–gooseberry hybrid

[face page 74

A DESCRIPTION AND CLASSIFICATION OF CERTAIN PLUM ROOTSTOCKS

By H. M. TYDEMAN

The twenty-three varieties of plum rootstocks described in this paper are those considered to be of the greatest interest to commercial growers. Some have been used for a long period, though several have proved by their behaviour in the nursery or plantation to be less well-suited to the requirements of the industry than was supposed at one time. The use of these latter is being gradually discontinued, but they are still to be found in widespread circulation and their easy recognition is a matter of some importance. Others described have shown promise as rootstocks for plums or peaches and are gradually coming into general use, or are likely to do so in the near future.

Both Hatton (1921) and Maurer (1939) have published illustrated descriptions of some of these rootstocks. Maurer's descriptions, in German, are particularly detailed and he has attempted a classification based on vegetative characters. Henkes (1943) has also published, in Dutch, useful descriptions and illustrations of certain of the stocks, and seven of them have been illustrated and very briefly described by Garner (1946). These publications are not, however, generally available and almost the only assistance to identification readily to hand is in Ministry of Agriculture Bulletin 135, 'Fruit Tree Raising' (1949).

Origin of rootstocks

Little need be said as to the origin of many of the varieties described since they have long been in common use. Pershore, Brompton, Brussels, Common Plum, Common Mussel, Broad-leaved Shiny Mussel and the Narrow-leaved Shiny Mussel had been in use for many years when Hatton wrote of them thirty-five years ago. The Aylesbury or Michaelmas Prune, like the Pershore, was grown upon its own roots in certain localities for its fruits, before it began to arouse interest as a rootstock.

The Mussels, as a group, comprise a number of varieties, most of which have been under trial at East Malling from time to time. In addition to the three named above, the Flat-leaved and French Mussels seem likely to prove of value. The former, often called the Dutch Mussel, is frequently found mixed in batches of the Common Mussel and is of interest for its ready rooting propensities ; it came to us from Holland. The French Mussel, although received from an English nursery, originated on the Continent.

Numerous seedling selections of Myrobalan, Black Damas, and St. Julien have been made and tested at East Malling. Of these, it has only been thought necessary to give descriptions of four Myrobalan stocks, comprising the original Malling selection, Myrobalan B, and three new seedlings. Of a number of Black Damas selections, only Damas C has been included, while the four St. Julien varieties described represent the pick of an extensive collection.

Marianna, reputed to be derived from a hybrid between *Prunus cerasifera* and *P. munsoniana*, came originally from America where it was once widely used. Ackermann (Marunke) is a rootstock of German origin, coming from Thuringia and distributed by the firm of Ackermann. Gelekroos (Yellow Kroosjespruin) is well known in Holland, from whence it was obtained.

East Malling E.478 is a seedling bred by the writer and selected from a family, Brompton × Common Plum, in 1933. It shows some promise of making a useful rootstock for the production of trees of restricted vigour.

Descriptions

The descriptions in Tables I and II are based on one-year shoots growing in the layer beds. Those in Table I were made at the height of the growing season when the shoots were well developed, but had not completely ceased their growth. Those in Table II were compiled from dormant shoots in mid-winter. Observations were made during 1954, 1955 and 1956, and were confirmed, wherever possible, by measurements of the characters studied (Tables IV and V).

Of the twenty-three rootstocks described, sixteen have been grown as trees in an arboretum. These are now approaching maturity and the descriptions of flower and fruit characters (Table III) may be of value for identification.

The characters that have proved most useful for identification are similar to those used in

describing apple rootstocks (Tydeman, 1953, 1954, and 1955) and need not be discussed here. As in the previous papers, the descriptions have been kept as simple as possible.

With plums, less emphasis can be placed upon differences in size, shape, or pose of leaf stipules than was possible with the apples, since, in many varieties, the stipules drop early in the season and may be difficult to find on fully mature shoots. On the other hand, the small glands at the base of the leaf blade often provide a useful clue to recognition.

Classification

Although it must be assumed that the plum rootstocks described comprise strains from the four species, *Prunus cerasifera, P. domestica, P. insititia,* and *P. spinosa,* it would be a matter of some difficulty to assign many of the varieties to any particular species ; species differences could certainly not be used with any confidence for classification. The *P. cerasifera* plums, which include the Myrobalans and, rather more doubtfully, Marianna, form a fairly clearly defined group with characteristic leaf shape, colour, and pose. Among the other varieties; *P. domestica* traits are often so blended with those of *P. insititia* or *P. spinosa* as to make assignment to one or other species a matter of conjecture. For example, of the St. Juliens, considered by most botanists to belong to *P. insititia* (Hedrick, 1938 ; Taylor, 1949), both the C and K strains have points of resemblance to such typically *P. domestica* plums as Pershore and Brussels. Considerable difficulty has been experienced in finding characters sufficiently distinctive and consistent to form the basis of a system of classification, but the groupings set out in the table that follows have been found in practice to be of assistance in the identification of the varieties.

SCHEME FOR THE IDENTIFICATION OF CERTAIN PLUM ROOTSTOCKS DURING SUMMER

A. PERSHORE GROUP. Vigorous, stout, *stiff,* reddish or purplish shoots with large, deep green leaves.

1. Lenticels on the shoots numerous.

a. *Edges of the leaves with rounded, crenate teeth.*

Very flat or convex, smooth leaves with distinct glands and leaf stalks purplish on the backs, on hairy shoots .. .. **Brussels**

Broad, much folded and twisted leaves with very indistinct glands and leaf stalks green on the backs, on almost hairless shoots .. .. **Brompton**

b. *Edges of the leaves with serrate teeth.*

Flat or slightly upfolded, rather drooping leaves with distinct glands, on almost hairless shoots .. .. **Pershore**

B. BLACK DAMAS GROUP. Shoots usually rather less vigorous and stout than in the Pershore group, *flexible,* usually with numerous laterals and spines ; leaves usually of medium size, flat or shallowly upfolded.

1. Lenticels on the shoots numerous.

b. *Edges of the leaves with serrate teeth.*

Dull green, medium oval, shallowly upfolded leaves with slightly waved margins and distinct glands usually along the stalks .. .. .. **Ackermann Marunke**

Deep bright green, very glossy, narrow, flattish, horizontal leaves, often twisted on the stalks with indistinct glands .. .. .. **Narrow-leaved Shiny Mussel**

2. Relatively few lenticels on the shoots.

a. *Edges of the leaves with rounded, crenate teeth.*

Bright yellowish green, rather flat, drooping leaves with distinct glands .. **Gelekroos**

Deep green, very glistening, broad leaves only slightly upfolded and shallowly waved with indistinct glands .. .. **Broad-leaved Shiny Mussel**

b. *Edges of the leaves with serrate teeth.*

Bright deep green, broad leaves with shortly waved margins, downturned tips and indistinct glands .. .. **Black Damas C**

Dull greyish green, fairly broad, very flat or convex, smooth leaves held out horizontally .. .. **Flat-leaved Mussel**

Smallish, deep greyish green, broad, rather crinkled leaves with slightly waved margins, and downturned, slightly twisted tips often somewhat curved over on the stalks .. .. **French Mussel**

ST. JULIEN GROUP. Usually only moderately tall, *stiff*, stocky shoots, often considerably spined, with rugose, thick or fleshy, often rather drooping leaves.

1. Lenticels on the shoots numerous.

a. *Edges of the leaves with rounded, crenate teeth.*

Medium sized, deep glaucous green, deeply waved, rather rugose leaves on bluish purple shoots .. .. **St. Julien A**

b. *Edges of the leaves with serrate teeth.*

Smallish to medium sized, oval, flattish, smooth, rather drooping, bright green leaves on greenish shoots .. .. **St. Julien K**

Largish, oval, somewhat rough, deep greyish green, slightly drooping leaves with a distinct basal sinus on deep brownish purple shoots .. **Aylesbury Prune**

2. Relatively few lenticels on the shoots.

a. *Edges of the leaves with rounded, crenate teeth.*

Medium sized, broad, deeply waved, downcurled or drooping, dull greyish green leaves, hairy on the under side with distinct glands .. .. **St. Julien C**

COMMON PLUM GROUP. Shoots not usually very vigorous, often rather spreading, slender, *flexible*, often fairly clean but occasionally spiny, with smallish, dark green, rough leaves.

1. Lenticels on the shoots numerous.

b. *Edges of the leaves with serrate teeth.*

Small, deep green, oval, shallowly waved, slightly upfolded leaves, somewhat upturned on the stalks with indistinct glands .. .. .. **St. Julien J**

Smallish, dark blackish green, medium oval, shallowly upfolded leaves with deeply waved, upturned margins, held horizontally with the tips downturned .. .. **Common Mussel**

2. Relatively few lenticels on the shoots.

a. *Edges of the leaves with rounded, crenate teeth.*

Smallish, rather oblong, deep greyish green, shallowly waved, rather rugose leaves on shortish, upcurved stalks with distinct glands .. **Common Plum**

b. *Edges of the leaves with serrate teeth.*

Small, deep green, medium oval, shallowly upfolded leaves with shortly waved edges, held outwards but somewhat twisted on the stalks .. **East Malling E.478**

MYROBALAN GROUP. Vigorous ; shoots long, *very flexible*, reddish brown or greyish brown with much dull green on the shaded side, smooth, almost glabrous and often very shiny, with fairly large, long, narrow, thin, smooth, almost hairless, somewhat drooping leaves with very indistinct glands and finely serrate teeth.

1. Lenticels on the shoots numerous.

b. *Edges of the leaves with serrate teeth.*

Bright yellowish green, flattish, somewhat drooping leaves with finely waved and frilled margins on deep purple stalks .. .. **Belgian Myrobalan**

Leaves usually somewhat larger than on Belgian Myrobalan, deep green, shallowly waved and upfolded on dull green stalks .. .. .. **Myrobalan Blanc**

Leaves usually narrower and more elliptical than on the Myrobalans, deeply upfolded, smooth and shiny, on deep red stalks and bright, reddish brown shoots .. .. **Marianna**

2. Relatively few lenticels on the shoots.

b. *Edges of the leaves with serrate teeth.*

Bright grass green, fairly smooth, rather flat or only slightly upfolded, drooping leaves with deep purple stalks on very shiny, bright purplish brown shoots .. .. **Myrobalan 29**

Deep green, narrow, crinkled, slightly drooping, often rather tattered leaves with dull green stalks on bright reddish brown smooth or slightly lumpy shoots .. .. **Myrobalan B**

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Summary

Descriptions and illustrations are given of twenty-three varieties of plum rootstocks of importance or interest to the commercial grower or nurseryman, together with a classification based on certain easily recognizable characters.

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Author's Note

The description of the Malling series of apple rootstocks, given in the Annual Report for 1954, and this paper upon selected plum rootstocks, have been based upon studies conducted simultaneously on all the rootstocks described in each series over the two or three seasons preceding the publication of the description. It is desired to make full acknowledgement of the valuable preliminary work of Mr. J. Floor on this subject carried out at East Malling between 1942 and 1944 on the Malling series of apple rootstocks.

It is regretted that this due acknowledgement was, through an oversight, not included in the paper upon the Malling series of apple rootstocks published in 1955.

Table IV

Dimensions of various foliage characters

(Averages of fifty leaves)

Rootstock	Leaf blade						Leaf stalk		Stipules			
	Length mm.	Breadth mm.	Breadth expressed as a % of length	Length of leaf tip mm.	Expressed as a % of length of leaf blade	Number of serrations	Length mm.	Expressed as a % of length of leaf blade	Length mm.	Expressed as a % of length of leaf stalk	Breadth mm.	Expressed as a % of length of stipule
Ackermann Marunke	57	41	72	5	9	81	10	18	6	60	1	17
Aylesbury or Michaelmas Prune	73	48	66	5	7	94	13	18	7	54	1	14
Black Damas C	48	37	77	3	6	84	7	15	7	100	1	14
Brompton	79	65	82	6	8	86	12	15	6	50	1	17
Brussels	93	64	69	5	5	67	19	20	7	37	1	14
Common Plum	53	37	70	3	6	82	10	19	7	70	1	14
East Malling E.478	46	33	72	4	9	89	6	13	5	83	1	20
Gelekroos	74	52	70	7	9	76	20	27	4	20	1	25
Marianna	70	37	53	5	7	162	14	20	7	50	1	14
Mussel, Common	64	44	69	6	9	63	13	20	5	38	1	20
Mussel, Broad-leaved shiny	62	47	76	5	8	70	19	31	3	16	1	33
Mussel, Narrow-leaved shiny	55	33	60	5	9	70	11	20	2	18	1	50
Mussel, Flat-leaved	63	46	73	6	10	78	14	22	5	36	1	20
Mussel, French	54	41	75	6	11	80	11	21	4	44	1	25
Myrobalan B	62	32	52	7	11	97	8	13	7	87	1	14
Myrobalan, Belgian	69	42	61	13	19	98	7	10	8	114	1	12
Myrobalan Blanc	74	45	61	13	18	101	9	12	7	78	1	14
Myrobalan 29	86	48	56	13	15	144	12	14	11	92	1	9
Pershore	78	61	78	5	6	96	19	24	9	47	1	11
St. Julien A	58	36	62	5	9	77	12	21	5	42	1	20
St. Julien C	62	46	74	3	5	93	9	14	8	89	2	25
St. Julien J	40	27	67	1	2	75	6	15	4	67	1	25
St. Julien K	56	38	68	4	7	69	11	20	9	82	2	22

Table V

Dimensions of certain characters associated with the shoots during dormancy

(Averages of fifty measurements)

Rootstock	Diameter of Shoots					Dimensions of Buds				Length of an internode mm.	Lenticels—number per centimetre of shoot
	Between the buds mm.	Across the buds mm.	Percentage increase	Through the buds mm.	Percentage increase	Length (*L*) mm.	Breadth (*B*) mm.	Length expressed as a % of breadth	Size ($\frac{1}{2}$ *LB*) sq. mm.		
Ackermann Marunke	5·7	6·4	12	7·3	28	3·1	3·6	86	5·6	26	40
Aylesbury or Michaelmas Prune	6·1	6·1	—	7·3	20	2·8	3·0	93	4·2	20	23
Black Damas C	5·5	5·6	2	6·6	20	2·0	2·2	91	2·2	18	16
Brompton	5·4	5·6	4	6·9	28	2·1	2·1	100	2·2	22	29
Brussels	6·4	6·4	—	8·5	33	1·8	1·9	95	1·7	22	32
Common Plum	6·4	6·7	5	7·7	20	2·1	2·4	88	2·5	22	9
East Malling E.478	4·9	4·9	—	6·5	33	2·0	1·8	111	1·8	24	12
Gelekroos	5·6	5·9	5	7·9	41	2·9	2·7	107	3·9	26	7
Marianna	6·7	6·8	2	7·7	15	1·3	1·8	72	1·2	26	32
Mussel, Common	4·3	4·4	2	5·6	30	1·7	1·8	94	1·5	13	23
Mussel, Broad-leaved shiny	6·4	6·5	2	8·4	31	1·9	2·0	95	1·9	23	9
Mussel, Narrow-leaved shiny	4·6	4·7	2	6·9	50	2·7	2·5	108	3·4	20	27
Mussel, Flat-leaved	5·7	5·8	2	6·8	19	1·3	1·2	108	0·8	35	5
Mussel, French	5·3	5·3	—	6·6	25	1·8	1·9	95	1·7	17	3
Myrobalan B	6·8	6·9	2	8·3	22	1·1	1·5	73	0·8	22	5
Myrobalan, Belgian	6·5	6·7	3	8·3	28	1·0	1·4	71	0·7	25	33
Myrobalan Blanc	6·6	6·8	3	7·8	18	1·1	1·6	69	0·9	30	40
Myrobalan 29	6·2	7·3	18	8·6	39	1·3	1·6	81	1·0	19	7
Pershore	6·2	6·2	—	7·7	24	2·3	2·3	100	2·6	20	59
St. Julien A	6·6	6·7	2	8·4	27	2·6	2·8	93	3·6	21	39
St. Julien C	5·5	5·5	—	7·4	35	1·6	1·7	94	1·4	25	13
St. Julien J	5·2	5·4	4	6·2	19	1·4	1·9	74	1·3	19	64
St. Julien K	5·8	6·0	3	7·2	24	1·9	2·3	83	2·2	15	62

Fig. 1

Ackermann Marunke. Flexible, rather zigzagged, bright brownish red, smooth shoots with very distinct lenticels and medium-sized or smallish, oval, smooth, shallowly upfolded, dull green leaves with distinct glands often scattered along the stalks

Fig. 2

Aylesbury or Michaelmas Prune. Erect, stiffish, deep brownish purple, slightly ridged shoots with largish, oval, rather rough leaves with a distinct basal sinus

facc page 80

FIG. 3

Black Damas C. Fairly long, flexible, bright brownish red, ridged shoots with smallish, broadly oval to almost circular, bright green leaves with shortly waved edges and long, spreading stipules

FIG. 4

Brompton. Vigorous ; erect, stiff, bright brownish red to purple, waxy, smooth shoots with large, deep greyish green, almost circular, much folded and twisted leaves with waved and folded margins and downturned, twisted tips

FIG. 5

Brussels. Long, fairly erect, stiff, dull brownish purple, ridged shoots, covered with fine greyish bloom ; large, oval, flat or slightly convex, deep green leaves, held horizontally or slightly upturned

FIG. 6

Common Plum. Rather spreading, flexible, somewhat spiny, dull reddish brown shoots with smallish, oval or oblong, dark greyish green, rugose, shallowly upfolded leaves with waved margins on shortish, upcurved stalks

FIG. 7

East Malling E.478. Vigorous ; slender, flexible, bright brownish red shoots with smallish, oval, waved, deep green, crinkled leaves

FIG. 8

Gelekroos. Flexible, erect, somewhat zigzagged, deep brownish red, smooth shoots with largish, oval, flat or shallowly upfolded, yellowish green, drooping leaves with rounded, downturned teeth

FIG. 9

Marianna. Long, straggling, flexible, bright reddish brown, smooth and polished shoots with largish, elliptical, upfolded, bright green, shiny, thin leaves, variably posed

FIG. 10

Mussel, Common. Slender, flexible, spiny, deep greyish purple, faintly pubescent, smooth shoots with medium-sized or small, oval, dark blackish green, slightly upfolded, rugose leaves with waved margins

FIG. 11

Mussel, Broad-leaved Shiny. Stoutish, flexible, bright brownish red to greyish purple, faintly pubescent, smooth shoots with medium-sized, broadly oval, flattish, deep green, very glossy leaves with shallowly waved margins and long stalks

FIG. 12

Mussel, Narrow-leaved Shiny. Rather slender, flexible, bright reddish brown shoots with large green patches, with narrowly ovate, flattish or slightly convex, bright green, very glossy leaves, often twisted on the stalk

FIG. 13

Mussel, Flat-leaved. Slender, straggling, flexible, faintly pubescent, deep greyish purple shoots with medium-sized, broad, flat or slightly convex, outturned, smooth, dull greyish green leaves often without stipules

FIG. 14

Mussel, French. Rather straggling, shortish, flexible, dull greyish purple, faintly pubescent shoots with smallish, broad, slightly waved and crinkled, greyish green leaves with downturned and somewhat twisted tips

FIG. 15

Myrobalan B. Vigorous, stoutish, flexible, reddish brown shoots with considerable green patches, with medium-sized, narrowly ovate, deep green, crinkled leaves with slightly waved margins, often rather tattered

FIG. 16

Myrobalan, Belgian. Vigorous, stoutish, flexible, deep brownish purple, smooth shoots with largish, narrowly ovate, bright yellowish green, somewhat drooping leaves with finely waved and frilled margins

FIG. 17

Myrobalan Blanc. Vigorous, stoutish, flexible, deep greyish purple, smooth shoots with large, narrowly ovate, shallowly waved and upfolded, deep green leaves

FIG. 18

Myrobalan 29. Vigorous, long, stoutish, flexible, bright brownish purple, very smooth, shiny shoots with narrowly ovate, shallowly upfolded, bright grass green, rather drooping leaves

FIG. 19

Pershore. Long, erect, stoutish, stiff, deep reddish purple, ridged shoots with large, bright green, crinkled, flat or slightly upfolded leaves with broadly waved, slightly upturned margins, somewhat drooping on the stalk

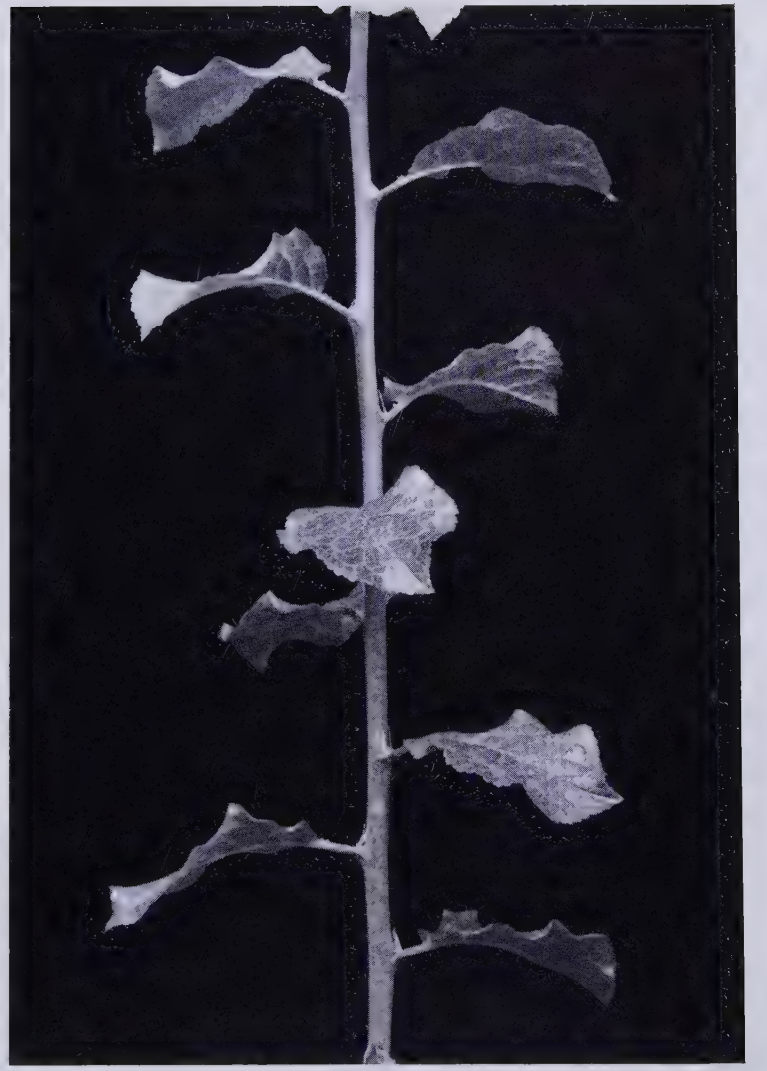


FIG. 20

St. Julien A. Stocky, stiffish, erect, deep bluish purple, ridged shoots with medium-sized, deep glaucous green, deeply waved, rather rugose leaves with downcurled tips

FIG. 21

St. Julien C. Stocky, stiffish, erect, bright purplish red, ridged shoots with medium-sized, deep greyish green, broadly oval, upcupped, down-curved or drooping leaves with waved margins

FIG. 22

St. Julien J. Long, slender, flexible, rich brownish purple, smooth shoots with small, oval or obovate, deep green, flattish, rugose, slightly upturned leaves with shallowly waved margins

FIG. 23

St. Julien K. Stocky, stiffish, dull green shoots, much tinged with brownish red with bright green, smallish to medium-sized, oval, flattish, drooping leaves with shortly waved margins

Ackermann Marunke

Aylesbury or Michaelmas Prune

Black Damas C

Brompton

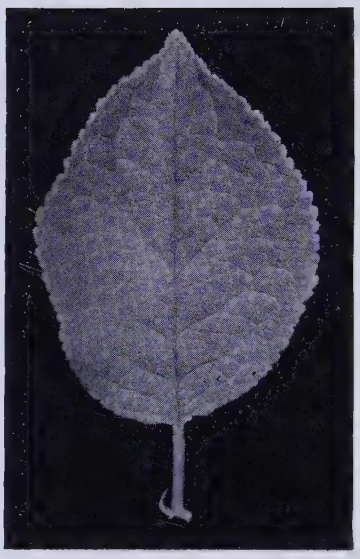
Brussels

Common Plum

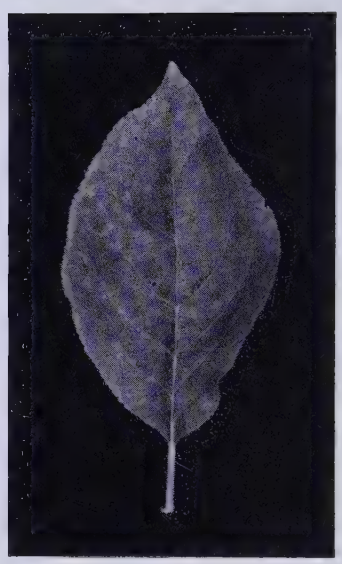
FIG. 24

Leaves of plum rootstocks

East Malling E.478



Gelekroos



Marianna

Mussel, Common

Mussel, Broad-leaved shiny

Mussel, Narrow-leaved shiny

FIG. 25

Leaves of plum rootstocks

Mussel, Flat-leaved

Mussel, French

Myrobalan B

Myrobalan, Belgian

Myrobalan Blanc

Myrobalan 29

FIG. 26

Leaves of plum rootstocks

Pershore

St. Julien A

St. Julien C

St. Julien J

St. Julien K

FIG. 27

Leaves of plum rootstocks

FIG. 28

Dormant shoots of plum rootstocks

East Malling E.478 | Gelekroos | Marianna | Mussel, Common | Mussel, Broad-leaved shiny | Mussel, Narrow-leaved shiny

FIG. 29

Dormant shoots of plum rootstocks

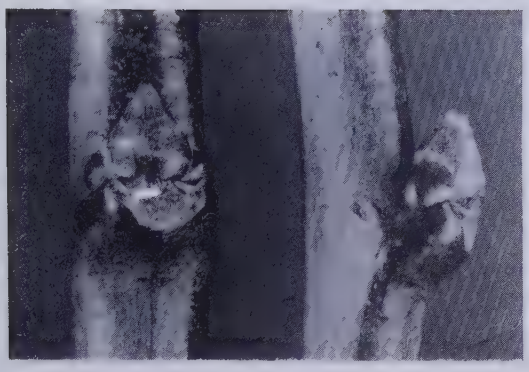
Mussel, Flat-leaved | Mussel, French | Myrobalan B | Myrobalan, Belgian | Myrobalan, Blanc | Myrobalan 29

Fig. 30

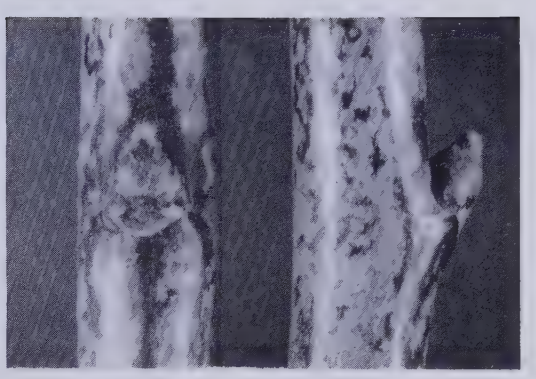
Dormant shoots of plum rootstocks

FIG. 31

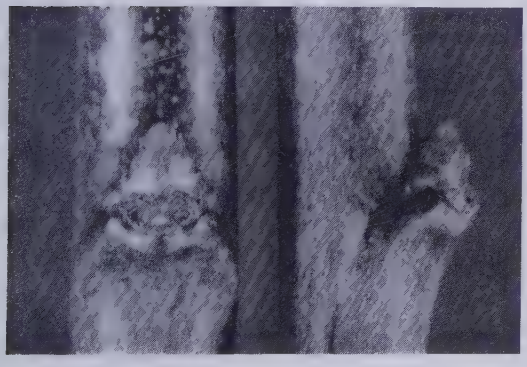
Dormant shoots of plum rootstocks



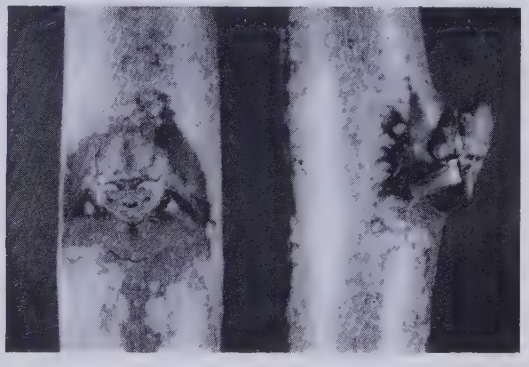
Ackermann Marunke



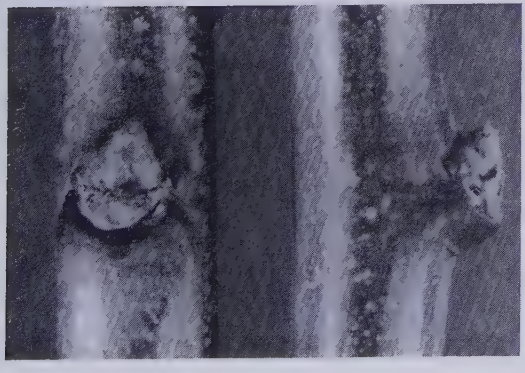
Aylesbury or Michaelmas Prune



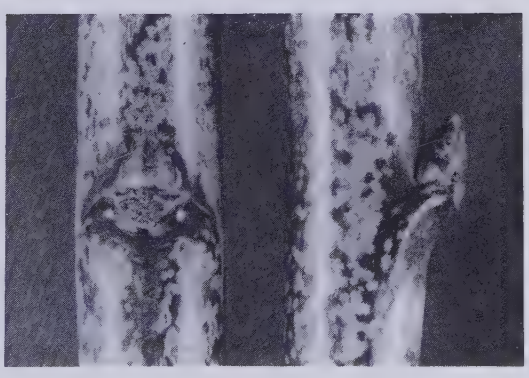
Black Damas C



Brompton



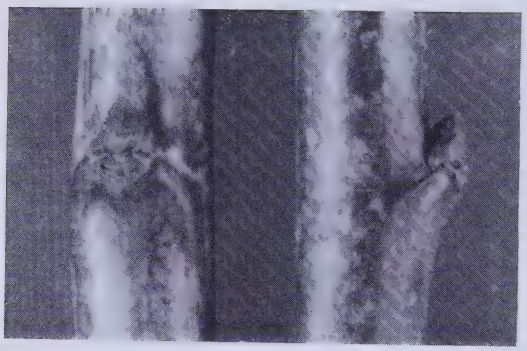
Brussels



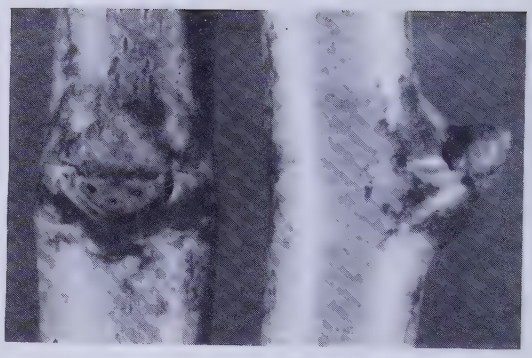
Common Plum

FIG. 32

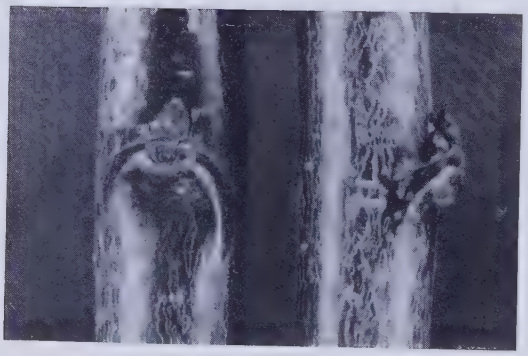
Nodes and buds (enlarged) of plum rootstocks in winter



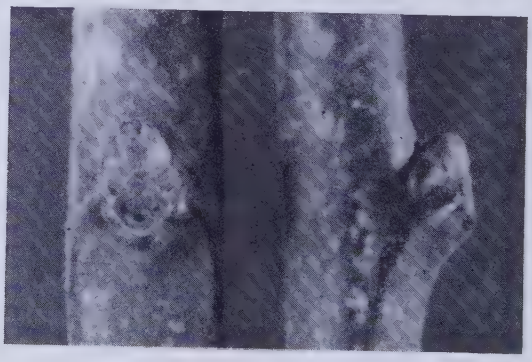
East Malling E.478



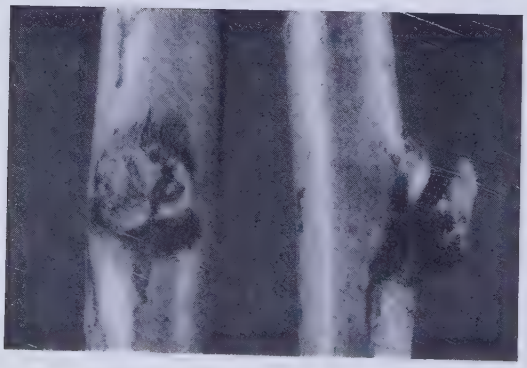
Gelekroos



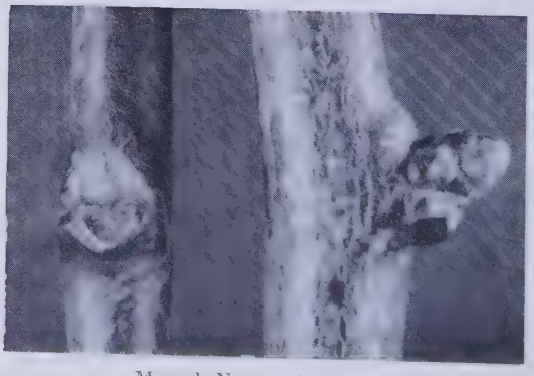
Marianna



Mussel, Common



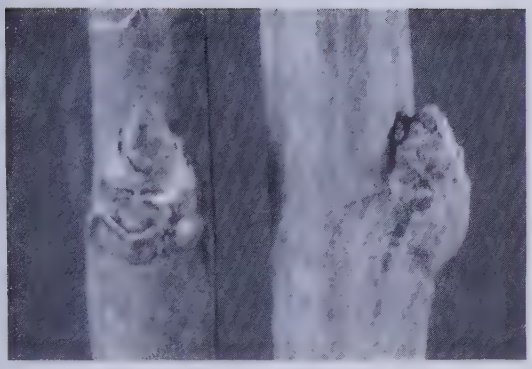
Mussel, Broad-leaved shiny



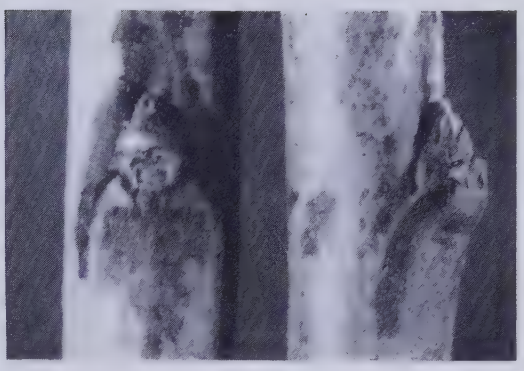
Mussel, Narrow-leaved shiny

FIG. 33

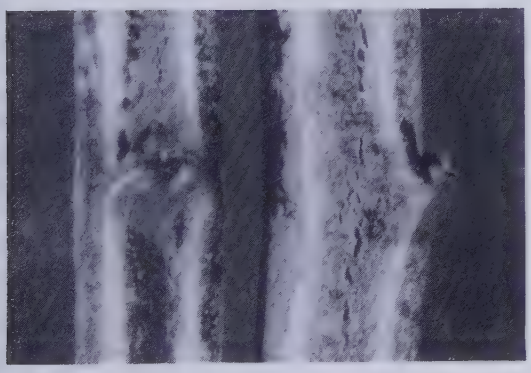
Nodes and buds (enlarged) of plum rootstocks in winter



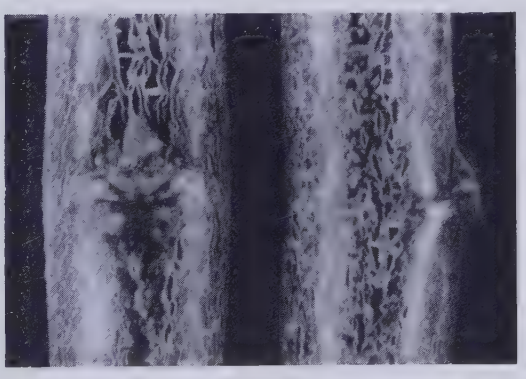
Mussel, Flat-leaved



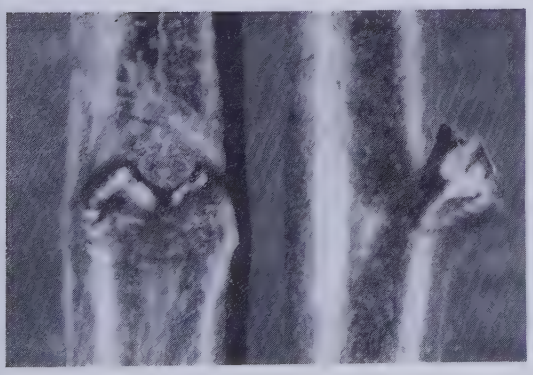
Mussel, French



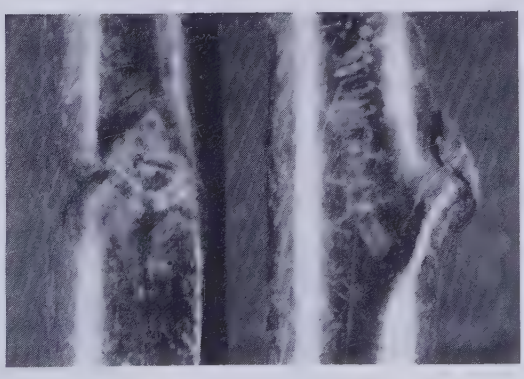
Myrobalan B



Myrobalan, Belgian



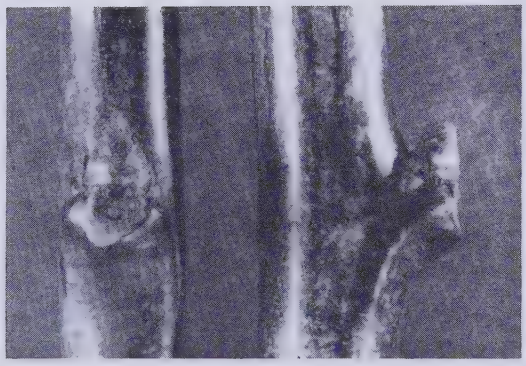
Myrobalan Blanc



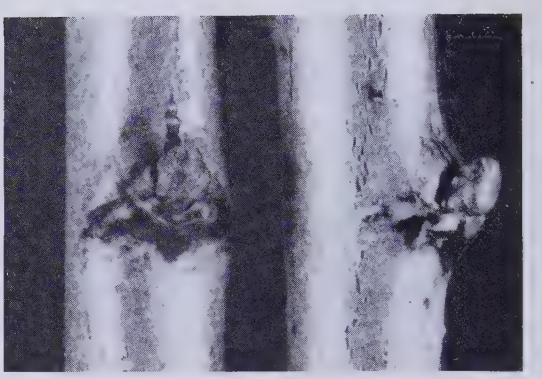
Myrobalan 29

FIG. 34

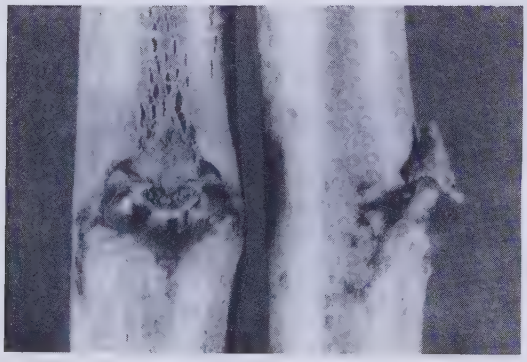
Nodes and buds (enlarged) of plum rootstocks in winter



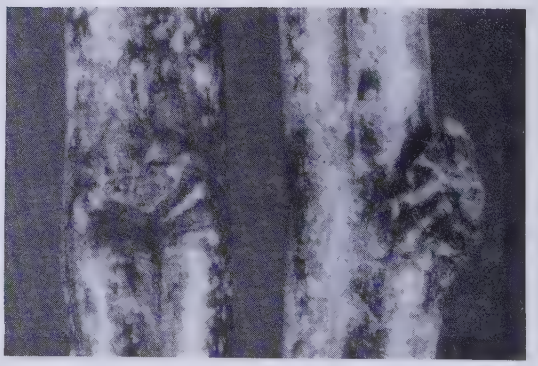
Pershore



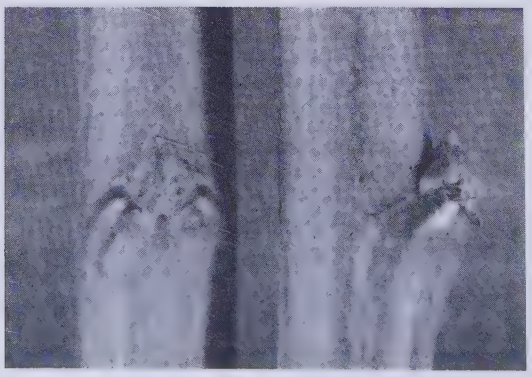
St. Julien A



St. Julien C



St. Julien J



St. Julien K

FIG. 35

Nodes and buds (enlarged) of plum rootstocks in winter

GROWTH AND CROPPING OF SOME NEW DESSERT APPLES

By A. P. PRESTON

This paper presents the first results from field trials in which three new dessert apples are compared with standard varieties of similar season. These new apples, Tydeman's Late Orange, Tydeman's Early Worcester, and Harvest, were bred at East Malling by H. M. Tydeman to extend the Worcester and Cox seasons. Early Worcester and Late Orange have already been introduced into commerce (Tydeman, 1946, 1949). The former, a second early apple, resulted from a cross between McIntosh Red and Worcester Pearmain. Late Orange, a seedling from a cross between Laxton's Superb and Cox's Orange Pippin, is a late keeping apple ; it was formerly known as Tydeman's Late Cox. Harvest, an early apple not yet introduced into commerce, is derived from the cross Devonshire Quarrenden × Worcester Pearmain.

Material

The first trial consists of Harvest and Beauty of Bath ; the second, Early Worcester and Worcester Pearmain ; and the third, Late Orange and Laxton's Superb. Each comprises 24 trees of each variety, half on M.VII and half on M.II. The varieties alternate in each row, the plots consisting of 8 trees either on M.VII or on M.II.

The trees were planted as maidens in December, 1946, at a spacing of 18 × 20 ft., on a sandy loam of the Malling Series. They have been renewal pruned.

For the first 8 years the trials were clean cultivated, with weeds allowed to grow each autumn ; they were grassed down in the spring of 1955.

Experimental results

Tree size

Measurements of the area of trunk cross-section at ten years of age show each of the three new varieties to be larger than the corresponding control, the largest difference being between Early Worcester and Worcester Pearmain, the former being almost twice the size of the latter. Trees of all varieties on M.II are larger than those on M.VII (Table I).

TABLE I

AREA OF TRUNK CROSS-SECTION (SQ. CM.), 1955

Rootstock	Harvest	Beauty of Bath	Early Worcester	Worcester Pearmain	Late Orange	Laxton's Superb
M.VII	93·2	81·9	93·6	48·7	75·6	67·3
M.II	118·7	102·8	123·4	63·7	93·5	81·0
Mean	105·9	92·3	108·5	56·2	84·5	74·1

Measurements made ten years after planting, show that trees of Harvest are taller but not so spreading as those of Beauty of Bath (Table II). Trees of Early Worcester are considerably taller

TABLE II

AVERAGE TREE HEIGHT AND SPREAD IN METRES, TEN YEARS AFTER PLANTING

Rootstock	Harvest		Beauty of Bath		Early Worcester		Worcester Pearmain		Late Orange		Laxton's Superb	
	Ht.	Spd.	Ht.	Spd.	Ht.	Spd.	Ht.	Spd.	Ht.	Spd.	Ht.	Spd.
M.VII	3·7	4·4	3·0	4·7	3·3	4·4	2·7	2·9	3·1	4·4	3·1	4·0
M.II	3·8	4·4	2·9	4·6	3·9	5·5	3·2	3·5	3·1	4·4	3·2	3·8

and more spreading than those of Worcester Pearmain. The heads of the Early Worcester trees tended to lean away from the prevailing wind during the early years and this made a somewhat lop-sided tree—but once the trees began to bear, this habit was largely corrected by the fruit weighing the branches down on to the windward side again. Trees of Late Orange are very similar in height and spread to those of Laxton's Superb—though in habit of growth and for ease of pruning Late Orange resembles its Cox's Orange Pippin parent more than Laxton's Superb.

Time of blossoming

Time of blossoming records made over a six-year period are summarized in Table III. The first blossoms of Beauty of Bath opened, on the average, on 29th April. The first flowers of Harvest opened on 7th May, but its blossom season (16 days) was shorter than that for Beauty of Bath (22 days). The times of blossoming of Early Worcester and Worcester Pearmain are, on the average, identical and the blossoming times for Late Orange and Laxton's Superb are also very close to one another.

TABLE III

TIME OF BLOSSOMING ; AVERAGE DATES, 1950-55

	Harvest	Beauty of Bath	Early Worcester	Worcester Pearmain	Late Orange	Laxton's Superb
First flower ..	7th May	29th Apr.	3rd May	3rd May	5th May	2nd May
Full bloom ..	14th May	6th May	10th May	10th May	11th May	10th May
80 per cent over	22nd May	20th May	19th May	19th May	19th May	20th May

Fruit yield

Time of picking.—Over a seven-year period Harvest was picked, on the average, eleven days after Beauty of Bath ; Early Worcester was picked nine days later than Harvest and fourteen days before Worcester Pearmain. In four seasons some of these early varieties were picked over before the fruit was finally cleared, in these cases the mean for the two picking dates has been included in the summary of time of picking (Table IV).

TABLE IV

TIME OF PICKING ; MEAN DATE, 1949–55*

Beauty of Bath	Harvest	Early Worcester	Worcester Pearmain	Laxton's Superb	Late Orange
4th Aug.	15th Aug.	24th Aug.	7th Sept.	12th Oct.	28th Oct.

* 1949 date excluded for Late Orange, see text.

In 1949 Late Orange was picked at the same time as Cox's Orange Pippin, and this led to severe shrivelling ; the picking date for that year has, therefore, been omitted from the summary. The picking date for Late Orange has normally varied from the last week in October to the first week in November, the mean date being 28th October, and this has been about a fortnight later than the picking date for Laxton's Superb. Bird damage can be troublesome with Late Orange, as this is one of the last varieties to be picked, and bird scaring precautions have been necessary.

Total crop.—The well-known shy bearing habit of Beauty of Bath, especially during the early years, has again shown up in this trial. Harvest trees have yielded a total crop nearly three times greater than that from trees of Beauty of Bath (Table V). Early Worcester yielded 37 lb. per tree

TABLE V

TOTAL CROP PER TREE (LB.), 1948–55

Rootstock	Harvest	Beauty of Bath	Early Worcester	Worcester Pearmain	Late Orange	Laxton's Superb
M.VII	128	47	182	208	242	307
M.II	177	61	174	223	268	278
Mean	152	54	178	215	255	292

ess than did Worcester Pearmain over the eight cropping years—but the earlier ripening of Early Worcester made the crops more valuable and this probably offset the difference in crop between the two varieties.

Over the same period Late Orange trees yielded 37 lb. per tree less than did Laxton Superb trees, but a fair comparison between these two varieties cannot be made on yield alone, fruit size and the biennial bearing habit of Laxton's Superb must also be taken into account.

With most varieties the larger trees on M.II yielded more heavily in total crop than did trees on M.VII but with the two exceptions, Early Worcester and Laxton's Superb, the differences were small.

Fruit size

The fruits were not thinned in these trials until 1955. In that year Worcester Pearmain was thinned to singles and Early Worcester, although it did not need thinning, was also thinned to keep the treatments on the two varieties strictly comparable.

Despite the very much heavier cropping of Harvest trees when compared with Beauty of Bath, the former variety bore larger fruits than the latter (Table VI). Early Worcester fruits were also larger than those of Worcester Pearmain.

TABLE VI

MEAN FRUIT SIZE ; NUMBER OF FRUITS TO 1 LB., 1948–55

Rootstock	Harvest	Beauty of Bath	Early Worcester	Worcester Pearmain	Late Orange	Laxton's Superb
M.VII	6·3	7·1	4·6	4·8	4·5	4·1
M.II	6·6	7·4	4·7	5·3	5·5	4·7
Mean	6·4	7·2	4·6	5·0	5·0	4·4

Over the eight-year period the average fruit size for Late Orange is a little smaller than that for Laxton's Superb—but the larger average fruit size of Laxton's Superb is due to the very large (though few) fruits carried in ' off ' years by this variety.

Slightly larger fruits were carried by trees on M.VII than by those on M.II, although with some varieties the differences were very small.

Regularity of bearing

The intensity of biennial fluctuation in bearing, factor ' I ' (Hoblyn *et al.*, 1936), has been calculated for each tree for Late Orange and Laxton's Superb (Table VII). This factor measures the intensity of the fluctuation and is arrived at by dividing the difference between consecutive pairs of years by their sum and multiplying by 100, 0 denoting equal numbers of fruits borne, and 100 no fruits borne at all in alternate years. On both rootstocks trees of Laxton's Superb were strongly biennial. Trees of Late Orange were less biennial than Laxton's Superb, though more so than Worcester Pearmain.

TABLE VII

INTENSITY OF BIENNIAL FLUCTUATION (I) IN NUMBER OF FRUITS, 1950–55

Rootstock	Late Orange	Laxton's Superb
M.VII	45	68
M.II	51	70
Mean	48	69

Discussion

The new varieties Harvest and Early Worcester, are two useful August apples coming as they do between Beauty of Bath and Worcester Pearmain. In shape, the fruits of Harvest resemble those of its maternal parent, Devonshire Quarrenden, they are almost completely red when fully ripe and they have a shiny skin. The fruit size of Harvest has been very satisfactory up to the tenth year ; it is possible, however, that this may deteriorate as the trees get older, as with Devonshire Quarrenden. It is not proposed, in the light of present knowledge, to release this variety, but its behaviour will continue to be watched at East Malling and in the National Fruit Trials.

The fruits of Early Worcester are similar in shape to those of Worcester Pearmain, they are scarlet-flushed over a creamy ground colour. The fruit has been harvested about a fortnight before that of Worcester Pearmain and on really early land the crop should be especially valuable. Fruit size has been good. Tip-bearing is a characteristic of Early Worcester, but this has not been a disadvantage where the trees have been either renewal pruned or regulated ; the lop-sided appearance of the head of the tree is usually corrected when the trees come into bearing.

Late Orange now occupies a useful place as a late keeping dessert apple to follow the normal Cox's Orange Pippin season. The fruits are roundish-oval in shape, flushed with a brown-red colour, with some russeting. Records made over a five-year period show Late Orange fruits, from trees on M.II, to be slightly redder than those of Laxton's Superb. Picked late it will keep without shrivelling. Storage experiments have shown this variety, stored at 37° F. (2·8° C.), to be in good condition with very little wastage until March, and stored at 31·5° F. (—0·3° C.) it kept until April, but the advantage gained in storing till April was not great (Kidd and West, 1952). Late Orange is less biennial than its Laxton's Superb parent. In vigour, branch formation, growth of laterals, and in pruning requirements, it resembles its Cox's Orange Pippin parent rather than Laxton's Superb.

Summary

Three dessert apple varieties, bred at East Malling, were planted with standard varieties of comparable season, on M.VII and M.II rootstocks, in field trials in 1946.

The varieties were Harvest (Devonshire Quarrenden × Worcester Pearmain), Tydeman's Early Worcester (McIntosh Red × Worcester Pearmain), and Tydeman's Late Orange (Laxton's Superb × Cox's Orange Pippin) compared with Beauty of Bath, Worcester Pearmain and Laxton's Superb.

Data are presented on tree size, time of blossoming, time of picking, total crop, fruit size and regularity of bearing.

Harvest, an early red apple, ripened about ten days after Beauty of Bath. Early Worcester ripened nine days later than Harvest and fourteen days before Worcester Pearmain. Late Orange was picked at the end of October and its season follows that of Cox's Orange Pippin.

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SUMMER GALE DAMAGE TO APPLE ROOTSTOCK AND PRUNING TRIALS IN 1956

By A. P. PRESTON

A gale in July, 1956, caused serious damage in many fruit areas, including East Malling. The soil was very wet at the time, in fact this was the wettest July since records began at East Malling in 1914. The trees were in full leaf and bearing heavy crops. Much fruit was blown down, but the most serious effect of the gale was the damage to the trees themselves. This provided an opportunity to examine the damage in relation to different rootstocks and pruning methods in experimental apple plantations on two different soils.

Topography and soils

Churchfields Plantation.—This plantation, situated 100–110 ft. above sea level on a gentle northern slope, is exposed along its south-west and western sides. The soil is mainly a sandy-loam of the Malling Series.

Larkfield Plantation.—This plantation varies from 85 to 95 ft. above sea level and is very exposed to the south and south-west. The soils consist of loamy-sands of the Lowlands Series and Bearsted Series.

The soils and experimental plots in both plantations have already been fully described (Preston and Stanton, 1947 ; Furneaux, 1954).

Experimental trees

The Churchfields Plantation contained trials of the fifteen Malling-Merton rootstocks and M.XXV, with trees on the older Malling rootstocks for comparison (Preston, 1955), all twelve years of age ; also trials of eighteen rootstocks of the M.IX Crosses (Preston, 1954), which were eleven years of age. This plantation also included two pruning trials, each twelve years of age, where tree shaping and pruning methods were being compared. These pruning trials and the Malling-Merton rootstock trials were duplicated in similar trials in the Larkfield Plantation. All trees were grown as bushes with trunks approximately 2 ft. high to the lowest branch. Trees in the rootstock trials were pruned by the regulated method, and clean cultivated.

All trees had been staked, with two uprights and a crossbar, and tied with hop string, in the ten years up to 1955. Those on Larkfield Plantation remained so in 1956.

In the Churchfields Plantation, the stakes had been removed during the winter of 1955 from all trees in the rootstock trials except those on M.IX and M.IV, also from trees on the vigorous and very vigorous clones of the M.IX Crosses, and from the pruning trial with trees on M.II.

Weather conditions

The month's rainfall up to 10 a.m. on 29th July 1956 was 3·66 in. and heavy rain on that day brought the total up to 4·01 in., so that the soil was very moist and soft at the onset of the gale. A strong southerly wind reached and maintained gale conditions between noon and 2 p.m. when Force 8 on the Beaufort Scale was recorded. The Dines anemometer, about 150 yds. from Churchfields Plantation, recorded gusts that reached 43 miles per hour several times during that period. Later in the day the wind veered to the south-west and moderated, although it remained strong for a further 24 hours.

Gale damage

The damage was recorded the day after the gale, affected trees being classified as : ' leaning slightly ', ' leaning severely ', or ' blown over '. The direction of leaning or falling, and any crotch splitting were also noted. Trees that were leaning slightly have been omitted from the summaries, since in most cases this had occurred in earlier years and is of little practical importance in the field. In almost all cases trees that were leaning or had been blown over were lying to the north or north-east. Very few cases of broken roots were seen.

Rootstock trials

The rootstocks in which damage occurred and the number of trees affected are shown in Tables I and II ; trees on the remaining rootstocks, viz. MM.101, MM.103, MM.104, MM.107, MM.110,

MM.113, MM.114, MM.115, M.I, M.VII and Ivory's Double Vigour, remained stable, as did trees on the following rootstocks of the M.IX Crosses, Nos. 3413, 3414, 3419, 3420, 3421, 3422, 3424, 3426, 3430, 3431, 3435, 3436, 3437, and 3438.

TABLE I

APPLE ROOTSTOCK TRIALS. NUMBER OF TREES DAMAGED ON CHURCHFIELDS PLANTATION (SANDY-LOAM)

Malling and Malling-Merton rootstocks				Malling rootstocks and M.IX Crosses				
Rootstock	No. of trees in trial	No. leaning severely	No. blown over	Rootstock	No. of trees in trial	No. leaning severely	No. blown over	No. splitting at crotch
MM.102	12	1	0	341	16	0	1	0
MM.105	12	1	0	3423	18	0	1	0
MM.106	12	2	0	3428	18	2	0	0
MM.108	12	2	0	3432	18	0	1	0
MM.112	12	2	0	M.IV	18	4	1	1
Northern Spy	12	1	0	M.II	36	2	1	1
M.IV	24	1	1	Crab C	18	0	0	2
M.II	12	1	0					

The damage in these trials was not very severe and little could be deduced from the small numbers of trees affected were it not that the results confirm and reinforce the record of anchorage made upon all trees in these trials five years previously. Then, at seven years of age, they were untied and their anchorage was measured by estimating their resistance to rocking by hand in three directions, the tests being carried out by two recorders working independently (Preston, 1954 ; 1955).

TABLE II

APPLE ROOTSTOCK TRIALS. NUMBER OF TREES DAMAGED ON LARKFIELD PLANTATION (LOAMY-SAND)

	Malling and Malling-Merton rootstocks				
Rootstock	MM.108	MM.109	MM.111	M.IX	M.XXV
No. of trees in trial	12	12	12	12	12
No. leaning severely	1	4	1	1	1

On Larkfield Plantation all the affected trees were Ellison's Orange, a vigorous growing variety, but on Churchfields Plantation almost equal numbers of Ellison's Orange and Cox's Orange Pippin trees were affected. Trees of Jonathan, which were comparatively short and drooping, were remarkably stable.

The rootstocks MM.104, MM.113, MM.114, and MM.115 showed up well in the earlier anchorage tests and trees on these were unaffected by the gale. The splitting at the crotch of two trees on Crab C (Table I) in no way reflects unfavourably upon that rootstock, but upon the narrow crotch angles of the primary branches.

Pruning trials

The damage in the pruning trials is summarized in Tables III and IV.

Delayed open-centre trees on M.II were more stable than open-centre trees in both plantations, but there was little difference between the two shapes with trees on M.IV. On Churchfields Plantation renewal pruned trees on M.II were more affected than established-spur pruned trees, and regulated trees were as badly affected as open-centre renewal pruned trees. On M.IV, in the same plantation, regulated trees were unaffected, whereas an average of 11 per cent of the established-spur pruned trees had either blown over or were severely leaning. On Larkfield Plantation, also, 28 per cent of the established-spur pruned trees were affected against only 12 per cent of the regulated trees, a difference doubtless due in part to the greater height of the former.

TABLE III

APPLE PRUNING TRIALS. NUMBER OF TREES DAMAGED ON CHURCHFIELDS PLANTATION (SANDY-LOAM)

	Open-centre		Delayed open-centre		Regulated
	Established-spur	Renewal	Established-spur	Renewal	
On M.II (in clean cultivation)					
Number of trees in trial ..	24	24	24	24	24
No. leaning severely	2	3	0	0	4
No. blown over	2	4	1	2	3
Percentage of trees affected ..	16	29	4	8	29
On M.IV (in grass)					
Number of trees in trial ..	40	—	40	—	40
No. leaning severely	0	—	1	—	0
No. blown over	5	—	3	—	0
Percentage of trees affected ..	12	—	10	—	0

TABLE IV

APPLE PRUNING TRIALS. NUMBER OF TREES DAMAGED ON LARKFIELD PLANTATION (LOAMY-SAND)

	Open-centre		Delayed open-centre		Regulated
	Established-spur	Renewal	Established-spur	Renewal	
On M.II (in clean cultivation)					
Number of trees in trial ..	24	24	24	24	—
No. leaning severely	2	2	0	0	—
No. blown over	0	0	0	0	—
Percentage of trees affected ..	8	8	0	0	—
On M.IV (in clean cultivation)					
Number of trees in trial ..	32	—	32	—	32
No. leaning severely	4	—	4	—	1
No. blown over	5	—	5	—	3
Percentage of trees affected ..	28	—	28	—	12

Trees on M.II on Larkfield Plantation, which were staked, suffered less than comparable trees on Churchfields Plantation, which were not staked.

Trees on M.IV were staked in both plantations, but those on Larkfield Plantation were more severely affected. This is doubtless because the plot on Churchfields Plantation had been grassed for the past three seasons and this contrast gives a measure of the extra stability given by grassing.

The plots of trees on M.IV and M.II were adjacent in both plantations.

Discussion

The gale damage once again emphasized the need for securing wide crotch angles for primary branches to avoid branch breakage ; and, more important still, the value of selecting rootstocks that will produce well-anchored trees. In this respect selections already made along these lines from new rootstock clones, e.g. MM.104 and MM.115, have proved themselves superbly anchored in the recent gale.

The figures do not suggest that regulated pruning, which tends to produce trees with a large surface area quickly followed by heavy bearing, need necessarily make trees any more liable to wind damage than renewal pruning. Trees on M.IV that were regulated acquitted themselves better than did established-spur pruned trees where, by leader tipping, a strong framework of branches had been

built up. A gale reaching Force 8 implies that a mean pressure of 5·4 lb. per sq. ft. is being applied to exposed objects. It should not be forgotten, however, that forces due to wind on an exposed object arise not only from the impact of air on the windward side, but also from the suction force on the leeward side. The relatively rigid branch system of a hard pruned apple tree offers a substantial area to these forces. A pendulous branch system, with thinner and less rigid branches, may result in lessening the tree area that is exposed to wind. Tree spacing may also affect wind damage, high density tree plots having been shown not only to reduce the wind passing through the plot, but to lead to heavier cropping per tree, when compared with low tree density plots (Preston, 1956).

These trials, containing as they do trees that have been staked for nine or ten years before the stakes were removed, pose the problem as to whether such trees, when the stakes are removed, are less stable than trees that have never been staked at all. Experiments to test this and other points in relation to anchorage have already been designed, using dessert varieties on M.II and MM.104. They are being planted in two exposed sites in Sussex and Worcestershire during the winters of 1956 and 1958.

Acknowledgement

My colleague, Mr. R. M. Fulford, rendered valuable and speedy assistance in recording some of the gale damage to the trees and my grateful thanks are due to him.

Summary

A gale, reaching Force 8 on the Beaufort Scale, occurred on 29th July, 1956, and caused considerable damage to fruit trees. This paper surveys the damage to twelve-year-old apple rootstock and pruning trials in two plantations on different soils. The records of damage are discussed in relation to rootstock selection, tree shape, method of pruning and the staking of trees.

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BLOSSOMING PERIODS OF SOME TREE FRUITS AT EAST MALLING

By ELIZABETH M. GLENN

In 1934 Beakbane, Chapelow and Grubb published blossoming dates for a large number of tree and soft fruit varieties at East Malling, and records of time of blossoming have since been continued on a smaller number of varieties, but including some of the newer ones.

Such observations have usually been made on two to four trees of each variety, and Fig. 1 shows the mean blossoming periods over the ten years, 1947-56, for plums, and over the seven years, 1950-56, for apples and pears.

The records made are the dates of (1) ' First ', the opening of the first flower ; (2) ' Full bloom ', when approximately 50 per cent of the flowers are open or over, and 50 per cent are not yet open ; and (3) ' Over ', when approximately 90 per cent of the petals have fallen.

A flower is recorded as open when the petals have separated sufficiently for the stamens to be visible.

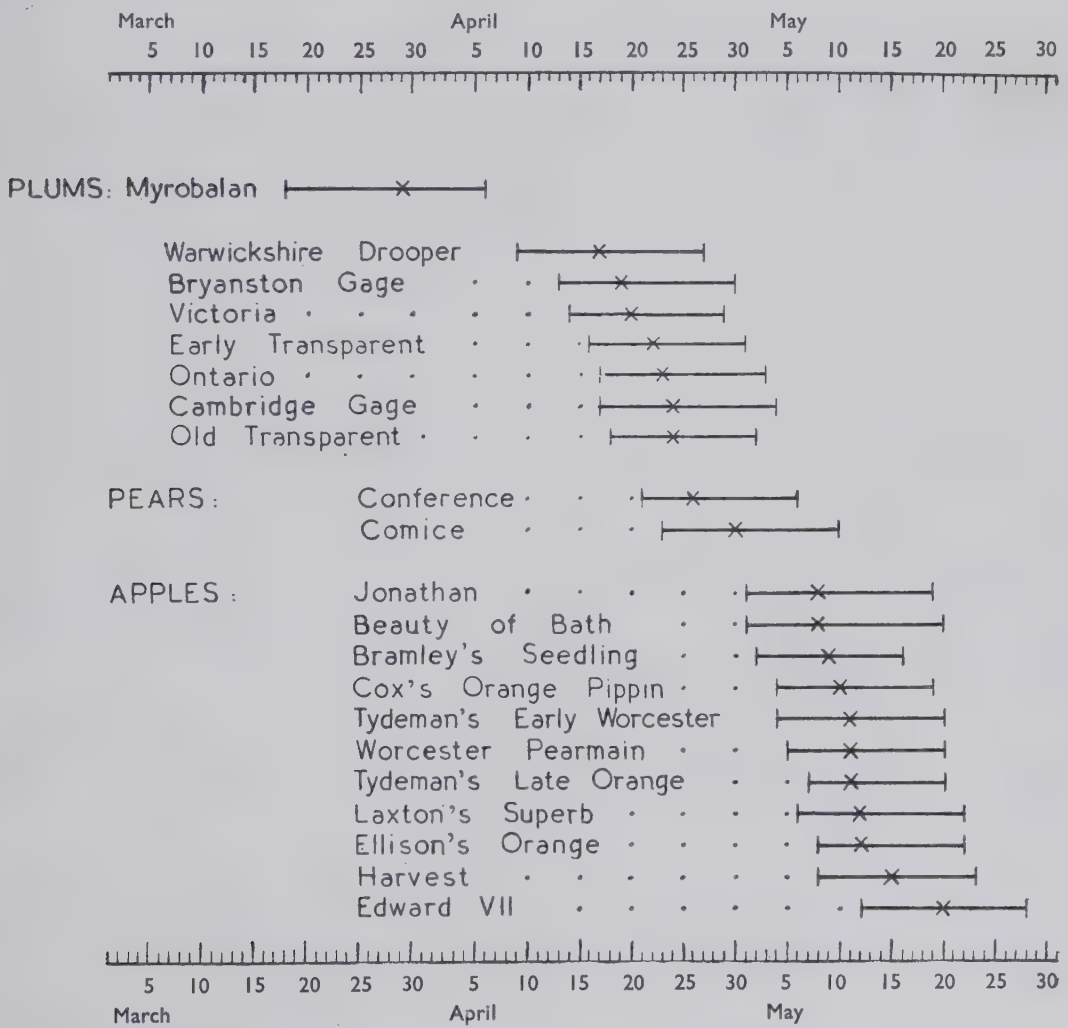

FIG. 1

Blossom periods for some plums, pears and apples. X = full bloom

The records on plums have been made on half-standard trees on Myrobalan B rootstock, planted in 1939, with the exception of the Myrobalan which were planted in 1921.

The pears are dwarf pyramids on Quince A, planted in 1944.

The apples, with the exception of Bramley's Seedling and Edward VII, were planted in 1945, and are regulated bush trees on M.II and M.VII. The Bramley's are on M.I, planted in 1920 ; and the Edward VII are spur-pruned trees planted in 1913 or 1914, and probably on M.II.

Fig. 1 shows the mean blossoming period for each variety, X marking the date of full bloom. The order of blossoming of the different varieties varies very little from year to year, although the actual dates vary widely.

Early blossoming does not necessarily connote early ripening. In plums the mean date for full bloom in Warwickshire Drooper is seven days earlier than that for Cambridge Gage, whereas the fruit normally ripens a fortnight to three weeks later. In apples the mean date for full bloom of Harvest is seven days later than that for Jonathan, although Harvest is an early ripening variety and Jonathan a late one.

The earlier blossoming fruits, such as plums, and particularly Myrobalan, are more variable in their dates of blossoming than are later blossoming fruits such as apples. Table I shows the actual

TABLE I

BLOSSOMING DATES OF MYROBALAN AND BRAMLEY'S SEEDLING

	' First '	' Full bloom '	' Over '
Myrobalan :			
1947	Apr. 10	Apr. 17	Apr. 22
1948	Mar. 8	Mar. 14	Mar. 17
1949	Mar. 15	Mar. 25	Apr. 1
1950	Feb. 17	Mar. 8	Mar. 18
1951	Mar. 20	Apr. 2	Apr. 10
1952	Mar. 4	Mar. 20	Mar. 28
1953	Mar. 25	Mar. 30	Apr. 7
1954	Mar. 17	Mar. 31	Apr. 14
1955	Apr. 3	Apr. 10	Apr. 23
1956	Mar. 22	Apr. 7	Apr. 13
Bramley's Seedling :			
1950	Apr. 26	May 5	May 13
1951	May 6	May 17	May 23
1952	Apr. 25	Apr. 30	May 6
1953	Apr. 29	May 6	May 14
1954	May 6	May 9	May 16
1955	May 3	May 12	May 24
1956	May 7	May 11	May 19

dates of first flower open, full bloom and 90 per cent petal fall for Myrobalan and for Bramley's Seedling. The date of full bloom of Myrobalan has varied between 8th March and 17th April, and that of Bramley's Seedling has varied between 30th April and 17th May. The date of first flower open in Myrobalan has ranged from 17th February to 10th April—a period of $7\frac{1}{2}$ weeks.

Table I also shows that 1948, 1950 and 1952 were early years, and that 1947 was a very late year.

Summary

The average dates of blossoming over a number of years are given for several varieties of plums, pears and apples.

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THIRTY-SIX-YEAR-OLD TREES OF CONFERENCE PEAR ON QUINCE ROOTSTOCKS

By DOROTHY J. WILSON

The classification of quince rootstocks at East Malling was described by Hatton in 1920 and 1928. As a result of his work three clones known as Quince A, Quince B, and Quince C were propagated and have since been widely grown. This report summarizes the behaviour of the oldest pear trees on these stocks at the Research Station.

Material

Quinces A, B, and C were budded with Conference pear in 1919 and sixteen trees on each stock were planted in two blocks, at 12 ft. square in 1921. Trees of Conference on other quinces planted at the same time showed varying degrees of incompatibility and few have survived (Hatton, 1935).

The trees on Quince C are known to be virus-infected, but all those on Quince A that have been tested appeared to be virus-free.

Tree size

The trunk girth has been measured annually and the final figure, converted to mean cross-sectional area of the trunk, is given for each rootstock in Table I. From the early years of the trial three of the trees on Quince A were noticeably smaller in trunk size than the rest on that rootstock. By 1948 these trees were dying back and were grubbed, but the cause was not established. If these trees are omitted from the mean, as in Table I, those on Quince A have grown the stoutest trunks. Trees on Quince B have, throughout their life, been somewhat smaller than those on A, and those on C have been markedly smaller than those on either A or B. The divergence of the means was apparent in 1927 and has persisted.

The trees were grown as open-centre bushes but the spread of the head has been limited for many years by the 12-ft. spacing.

Crop

The total crop per tree on each stock is given in Table I. Until 1933 (12 years from planting) the trees on Quince C had produced more fruit than those on A and B (Hatton, 1934), but subsequently they yielded less than the A and B trees in every year except one.

The mean weight of fruit per unit of trunk size (Table I) shows little difference between the rootstocks.

Fruit size, expressed as the weight of 100 fruits (Table I) is the mean for the period 1943–55, excluding 1946 when there was very little fruit and 1948 when samples were taken from two trees only. Quince C trees have generally given slightly smaller fruit than A and B trees, but the fruit from all three stocks has been rather small in most years.

TABLE I

DATA FROM 36-YEAR-OLD CONFERENCE PEARS ON QUINCE STOCKS

	No. of trees	Area cross-section of trunk, 1955 sq. cm.	Cumulative crop to 1955 lb.	Crop per unit cross-section area lb.	Mean weight 100 fruits lb.
Quince A	13	255·9	2,149	8·4	22·7
Quince B	16	236·6	2,105	8·9	23·3
Quince C	16	179·2	1,541	8·6	21·2

Conclusions

The continued growth and cropping of all three sets of trees to an age of 36 years from the bud is convincing evidence that pears on quince stocks need not be regarded as short-lived trees, even when closely spaced, provided the stock and scion are compatible.

Quinces A and B have remained closely similar in performance throughout the life of this trial. The choice of Quince A for general use has partly resulted from its better behaviour in the nursery.

If a more dwarfing stock for pears is required, a healthy stock of the vigour of Quince C or less remains to be found.

Summary

The tree size and crop records are given for 36-year-old trees of Conference pear on Quince A, B and C rootstocks. Cumulative yields show that the A and B stocks have outyielded C by 39 and 37 per cent, respectively.

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FROST DAMAGE RESEARCH EQUIPMENT AT EAST MALLING

By C. H. W. SLATER

In previous papers on frost research work at East Malling, references have been made to the equipment used, but no detailed descriptions have been published. The following paper describes the design and construction of some of the equipment which has proved valuable. This special equipment has also been found of interest to workers concerned with other aspects of micro-climatology and environmental control.

The frost damage research rooms

Natural frosts seldom provide ideal conditions for planned research on frost damage, and to supplement these a commercial cold storage chamber was converted into a frost research laboratory. The original storage chamber measured 18 ft. square and was 16 ft. high. This has been divided into four rooms consisting of a ' preparation room ', a ' spring frost room ', a ' winter frost room ' and an ' instrument room ', as shown in Fig. 1. The walls, of timber framing faced with either galvanized iron sheeting or tongued and grooved boards, are filled with granulated cork insulation, or cork slabs.

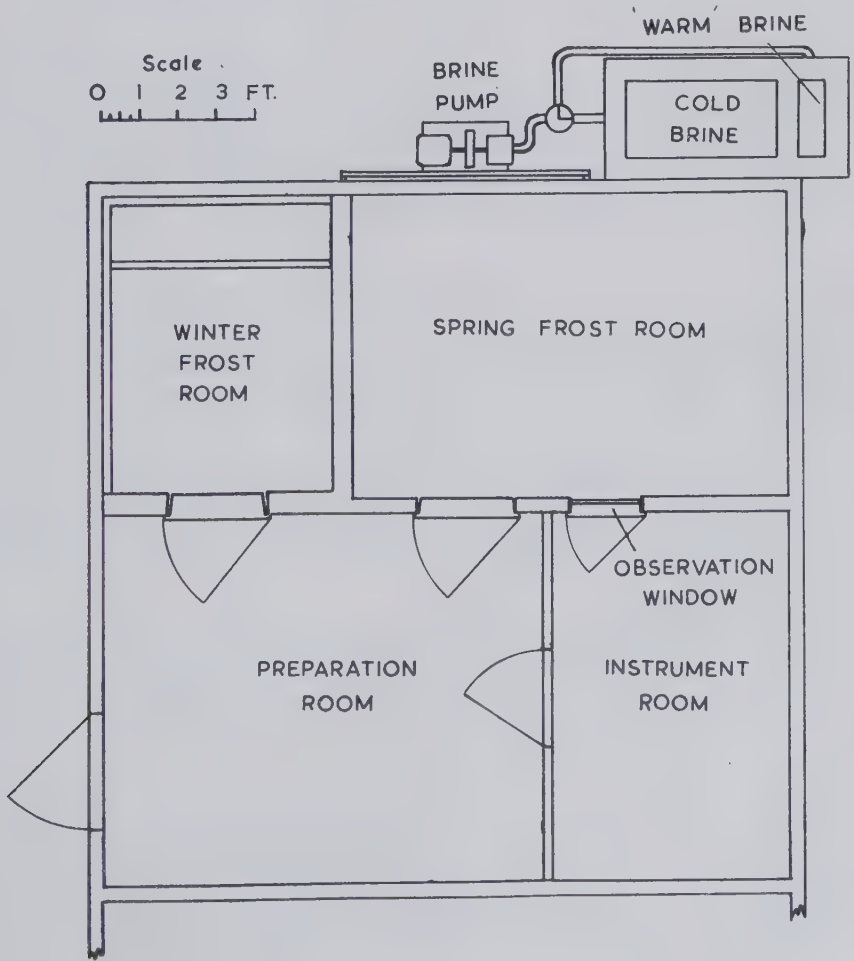

FIG. 1
Plan of frost research laboratory

The preparation room

The room measures 11 ft. 6 in. by 9 ft. 6 in. and is used for pre-freezing treatments of experimental material, such as inserting thermocouples, sampling, or labelling parts of the plants for future identification.

The spring frost room

This room was designed to permit plant material to be subjected to frosts resembling those experienced in spring. Provision was made for close control of rate of cooling and warming, as well as for maintaining any temperature down to about −9° C. (16° F.). The room measures 11 ft. 6 in. by 8 ft., and is 10 ft. high, so that small trees, grown in pots, can be brought in for freezing. The walls have cork insulation 4 in. thick, except for the wall next the winter frost room, which has 6 in. of cork.

Cooling is by calcium chloride brine circulated through 1½-in. gilled piping, which is arranged in three layers below, and spreading right across, the ceiling of the chamber. Each layer is controlled by a separate valve, and the total pipe length is 265 ft. . Gutters under the pipes carry away water when defrosting. The main brine tank is cooled by a triple cylinder compressor driven by a 3 h.p. electric motor, with thermostatic control to within 3° F. Very close control of the temperature of the *circulating* brine is maintained by a two tank system, as follows : The brine from the gilled pipes discharges into a second, smaller tank fitted beside the main tank. The second tank is not cooled but merely acts as a ' warm ' brine reservoir, excess brine flowing through an overflow pipe back into the main tank. A mixing valve enables either ' warm ' or cold brine, or any mixture of the two, to be pumped through the gilled cooling pipes. The valve is operated, by remote control, from the instrument room. The temperatures of the brine in the cold tank and of the brine entering and leaving the gilled pipes, are all measured with thermocouples. With this equipment the operator can control the cooling rate with great accuracy.

In the original layout the cold air fell by gravity from the cooling pipes and was further circulated by low-speed oscillating fans. This gave quite good results ; but in order to get still more even temperature throughout the room, a forced circulation system was later installed. This involved fitting a false ceiling of hardboard under the gutters, 8 ft. above floor level, to form a compartment in which the air is cooled by the brine pipes. The cold air is drawn down a central trunk by a fan, and expelled into the chamber under battens along the floor. The ' warm ' air is drawn from the top of the chamber into the ceiling space and there cooled. The air circulation rate is controlled by adjusting the fan speed. The fan is only used during experiments, pre-cooling of the chamber before experiments is by convection currents. During this pre-cooling period the temperature of the room is controlled by a bimetal helix thermostat in conjunction with a hotwire vacuum switch which switches the brine pump on and off. During a freezing run the compressor, brine pump, mixing valve, fans and heaters are all controlled from the instrument room, giving great flexibility of operation. The temperature variation from place to place in the room, during a run, with trees, is normally less than 0·2° C.

Two 1½-kw. electric heaters are used to warm the room and plant material at the end of the experiments. The heaters are mounted, near the floor, one on each end wall. The heaters have a low heat capacity and quickly cool when switched off, so enabling the operator to maintain control of the room temperature during the warming up period. During this period the central cooling fan is switched off and a second electric fan maintains air circulation in the room. The heaters can be controlled to maintain a constant warm temperature if required, using a thermostat in conjunction with a hotwire vacuum switch.

An insulated observation window is fitted in the dividing wall between the spring frost and instrument rooms. Apparatus and plant material can be observed during freezing experiments and notes on wilting, ice formation, etc., can be made without disturbing the air temperature inside the chamber.

Electrical apparatus in use inside the freezing chamber can be controlled from outside by using wander leads led through removable insulated hatches.

The winter frost room

This room measures approximately 5 ft. 8 in. square and is 7 ft. high. The walls and ceiling are insulated with 6 in. of cork and the floor is insulated with 3-in. cork slabs covered with 1½ in. of granolithic.

The cooling system is of the direct expansion type. The twin-cylinder, methyl chloride compressor, driven by a 2-h.p. electric motor, is mounted on top of the commercial store and the cooling coil is fitted behind an insulated bulkhead which forms a false wall in the freezing chamber. There is a 4-in. slot, 4 ft. long, running horizontally across the bulkhead 6 in. from the floor. Air is drawn from the room through this slot and over the cooling coils, by a 15 in. diameter electric fan. The

cold air is directed into the chamber through four openings each 6 in. wide and $7\frac{1}{2}$ in. long fitted with sliding covers which can be adjusted to regulate the air flow.

The rate of cooling can also be adjusted during an experiment, by means of a valve which regulates the flow of refrigerant, and two pressure gauges, recording the refrigerant pressure at the inlet to the compressor and at the exit from the cooling coil. When cooling the chamber before an experiment the temperature is controlled by a bimetal helix thermostat which switches the compressor on and off via a hotwire vacuum switch. The air-circulating fan normally switches on and off with the compressor ; but smoother control is obtained if the fan is kept running continuously during experiments. The minimum temperature obtainable is about —20° C. (—5° F.).

The cooling coils can be de-frosted without warm air entering the freezing chamber. Two hinged insulated plugs are fitted in the outside wall behind the bulkhead. The plugs are linked to two spring-loaded shutters which close the inlet and outlet holes in the bulkhead when the de-frosting plugs are opened. By this method, warm air from outside can circulate over the cooling coils, melting the ice layer without causing sudden temperature changes in the freezing chamber. As the plugs are closed the shutters open automatically and the normal air circulation continues.

A single $1\frac{1}{2}$-kw. heater of the type mentioned earlier is mounted on an asbestos sheet on the ceiling. Warming the room can be carried out gradually by switching off the compressor and using the heater with the circulating fan running. Cold air from the cooling coils then passes over the heater warming the room slowly. If quick heating is required, the de-frosting plugs are opened and the spring loaded shutters held open also. The fan then draws in warm air from outside which passes straight into the room and over the heater, so increasing the heating rate. The room can be maintained at a constant warm temperature by using a thermostat and a hotwire vacuum switch to control the heater.

The instrument room

It was found that the calibration of the sensitive temperature recording apparatus was affected by changes in their own temperature—particularly by waves of cold air when the doors of the freezing rooms were opened. Accordingly, an instrument room, 7 ft. 6 in. by 9 ft. 6 in., was partitioned off ; and this is maintained at a constant temperature by tubular heaters and a thermostat, providing good conditions both for operator and instruments. A 6-in. fan provides fresh air through a duct in the ceiling.

Apparatus

Standard Meteorological Office minimum thermometers are used for recording air temperatures where appropriate; and thermographs and hygrographs, when carefully calibrated, have also given good service. But the main serial temperature measurements in blossoms and other plant material, and in the air, are made with fine wire thermocouples. These have already been described (Slater, 1953). In conjunction with these thermocouples, either manual potentiometers or multi-point recorders are used. Two special potentiometers have been made and calibrated to read directly in tenths of a degree Centigrade. The first has a temperature range from 0° C. to plus or minus 20° C. The second has a modified circuit whereby readings can be taken at either side of 0° C. without operating a reversing switch. This simplifies reading temperatures at that part of the range which is most important in frost studies. The ranges of this potentiometer are +12° C. to —8° C. and +24° C. to —16° C.

The recorders used are as follows :

(1) A Cambridge high-speed 6-point recorder containing a D.C. amplifier. It has two temperature ranges, + 10° C. to —2·5° C. and +35° C. to —2·5° C. Both ranges are reversible. Temperatures are read at $2\frac{1}{2}$ sec. intervals, individual points being read once every 13 seconds.

(2) A Foster 6-point recording pyrometer fed through a Tinsley D.C. amplifier. The amplifier has three alternative range coils ± 5° C., ± 10° C. and ± 25° C. Temperatures are read at 10 sec. intervals, individual points being read once per minute.

(3) A modified Electroflo model 10304/100, 4-point recording thermometer fed through a Sunvic D.C. A1. Mk. II amplifier. The range of this instrument is continuously variable. Temperatures are read at $\frac{1}{2}$ min. intervals, individual points being read every 2 minutes.

(4) A Kent Multelec recording potentiometer which can be used as either a single point or two point instrument. When used as a two point instrument, each point is recorded for $\frac{1}{2}$ min. before changing to the next. As a single point instrument it records continuously. The range, as in the Electroflo, is continuously variable. The chart is 10 in. wide and chart speeds of 2, 4, and 6 in. per hour are provided. The instrument is mainly used for studying rapidly changing temperatures, particularly for studies of freezing of plant tissues under the microscope (Modlibowska and Rogers, 1955).

All the recorders mentioned so far rely on a mains electricity supply for their operation. For field work where there is no convenient electricity supply, a Cambridge Model A two-point recorder driven by clockwork is used. The two clockwork mechanisms, one to control the rate of operation and the second to supply the power for the switching and printing mechanism, have to be wound daily. The range of the instrument is + 80° F. to — 20° F., but by using double thermocouples the range is reduced to + 40° F. to —10° F., so giving a more open scale.

Rotating stand

When freezing clusters of blossoms cut from trees growing in the orchards, instead of whole trees in pots, a rotating stand is used to hold the clusters. The stand consists of two horizontal, concentric aluminium rings, with the smaller inner ring raised above the larger outer ring (Fig. 2). The rings are so designed that either large or small glass tubes filled with water, can be held in holes in the ring and clusters of flowers or single blossoms placed in the tubes. By using spring clothes pegs fixed to the rings, cut clusters or single blossoms can be held in wet cotton wool pads. The rings are supported from the rim of a 28-in. bicycle wheel which is held horizontally by its axle. The wheel is driven by a belt which passes round the spindle of a variable speed electric gramophone motor and round the rim of the bicycle wheel. By rotating the clusters in this manner positional effects are eliminated and the clusters are exposed to uniform freezing conditions.

Covered shelter for trees in pots

To ensure that blossoms will not be damaged before experiments, and that ' live ' blossoms after freezing will develop for future study, potted trees are grown in a birdproof shelter that can be completely covered with hessian on frosty nights. The frame is of welded steel tubes, and is clad with $\frac{3}{4}$-in. wire netting, with detachable panels at intervals along one side to allow easy removal of trees.

When there is danger of natural frost damaging the blossoms on the experimental trees, the whole shelter is covered at night with large hessian sheets. This cover maintains the temperature inside at from 1° F. to 5·5° F. warmer than outside. Over a period of 16 nights in April and May in 1956, the mean inside temperature was 3·6° F. warmer than outside.

Mobile instrument room

For field work on frost a modified Berkeley ' Messenger ' caravan is used as a mobile instrument room (Fig. 3). Its size, approximately 6 ft. by 12 ft., allows easy manipulation in orchards. The caravan is fitted with two bunks, one above the other, a drawer and cupboard unit with table top for recording equipment and a second cupboard unit containing separate cooking and washing compartments in the top. When these compartments are closed they form a further flat working surface. A removable folding table fits across the end of the caravan and this normally carries the potentiometer and its allied equipment. The caravan is supplied with electricity by temporary land line, to feed the recording equipment and for lighting and heating purposes.

Acknowledgements

Dr. W. S. Rogers played a large part in designing the frost research rooms and other special apparatus ; and the writer thanks him for help in preparing this paper. Thanks are also due to Messrs. J. and E. Hall Ltd., for technical advice and installation of the refrigeration equipment.

Summary

The construction and equipment of frost research rooms in which plants can be subjected to controlled cycles of freezing and thawing are described. Details are given of temperature recording apparatus, including a special potentiometer for use with thermocouples ; and also of a covered shelter for experimental material, and a caravan fitted as a mobile instrument room.

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Fig. 2
Rotating stand showing raspberry shoots held in spring clothes pegs

Fig. 3
Caravan fitted as mobile instrument room. Note white insulation on thermocouple wires for better visibility at night

[face page 96

WEATHER CONDITIONS DURING 1956

By G. F. TROWELL

East Malling Research Station

Unusual weather for the time of year occurred throughout much of 1956, many records being broken. For much of the first half of the year conditions were exceptionally dry, with May a good month for sunshine and temperatures. Dull cold, and extremely wet weather persisted throughout the summer, with gales and freak hailstorms, and brighter weather did not appear again until late September ; it was followed by a very dry autumn.

A new 35 years rainfall average has been calculated from our own East Malling records for 1922–1956, and it is this which is referred to subsequently, the older figures based on weighted averages for the period 1881–1915 (as used in the Monthly Weather Report of the Meteorological Office) being inserted in Table I for comparison. Rainfall during the year amounted to 24·69 in., 2·04 in. below average, and as in the past two years distribution was again unusual. January was the wettest month with 4·77 in., rain being recorded on 21 days, but the next two months were both very dry, February being the driest since 1934. May was also exceptionally dry, 0·61 in. being recorded on 6 days, 1·32 in. below average. The total rainfall for February, March, April, and May was 4·14 in. below average ; over the past 5 years rainfall during this period has been below average. July, on the other hand, was the wettest July since records began in August, 1914, with 4·01 in. of rain. The previous wettest July was in 1927 when 3·96 in. of rain fell. The heaviest day's rainfall of the year was on 8th July when 1·30 in. were recorded. August had rain on 21 days, making January and August the two months with the highest number of days on which rain fell in any month. Considering the general impression of a wet summer, averages may not appear very high, but the number of days on which rain fell was exceptional, rain being recorded on 70 days out of a 100 from 1st June to 8th September. After this date dry conditions were experienced, and even in October and November, usually the two wettest months of the year, rain was recorded on a total of only 25 days. The longest wet period of the year was between 23rd August and 6th September, and the driest period between 4th and 19th March.

Sunshine during the year totalled 1,469 hours, 94 hours below the 25-year average, and 163 hours below last year's total. May was the sunniest month of the year, 44·5 hours above average, but the next month was the dullest June since 1923, with only 139 hours of sunshine, 83 hours below average ; half of the month had less than 4 hours sunshine per day. The rest of the summer months were also well below average, the total sunshine for June–September being 169 hours below the 25-year average. December set up another record for 1956 as the dullest December since our observations began in 1914, only 12·2 hours sunshine being recorded, less than on 26th July, the sunniest day of the year, when 14·3 hours were recorded. The previous dullest December was in 1934.

Mean maximum screen temperatures were generally below average, especially in February, when for 12 days the maximum did not go above freezing. April, June, July, and August all had temperatures well below average, May being the only summer month above average. January and December mean maximum temperatures were above normal, the latter month being exceptionally mild. Mean minimum screen temperatures during January, July, September, October, and December were all above average. Yet another record was broken in February, the mean minimum, 24·4° F., being the lowest for February since records began, lower than in 1947 when the mean was 25·5° F. The highest screen temperature was 83° F., recorded on 26th July, and the lowest 11° F., on 4th and 21st February.

Ground frosts were the most frequent since 1945 when 100 were also recorded, the majority occurring in February. The number of ground frosts during April was high, 17 compared with 11 in 1955. No serious late spring frosts occurred, although one was recorded on 21st May, when the air temperature fell to 30° F., with a grass temperature of 25° F. (see Fig. 1). The last spring frost recorded in 1955 was on 22nd May. Although later than usual, Myrobalan B blossomed 11 days earlier than last year, but the first flowers on such varieties as Noble, Bramley, and Cox, were 5 or more days later than in 1955.

Cold north-easterly winds persisted throughout the second half of April, making pollination conditions poor for such varieties as Victoria Plum, Keepsake, and the early flowers of Early Rivers Cherry and Conference Pear (Fig. 1). Gale force winds of over 40 m.p.h. were recorded on 1st January and 29th July, the latter causing a large number of trees to be blown down or over. Damage was increased by the trees being in full leaf, and by ground conditions at the time being extremely wet,

Table I

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1956

East Malling

Month	Temperature in Screen					Number of Ground Frosts	Rainfall				Sunshine			Soil Temperatures			
	Mean maximum	Mean minimum	Highest	Lowest	Mean		Total in inches	Heaviest fall in a day	35* years' average	1922 1956 average	Total hours	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
January	44·6	33·8	54	24	39·2	17	4·77	0·91	1·96	2·46	55·3	1·8	47	36·7	37·7	40·0	42·7
February	35·6	24·4	53	11	30·0	26	0·79	0·14	1·85	1·95	57·3	2·0	68	32·0	33·5	36·7	40·1
March	50·5	35·4	63	22	43·0	15	0·67	0·28	2·01	1·57	159·9	5·2	123	40·2	40·4	40·9	40·7
April	52·5	34·3	68	26	43·4	17	1·14	0·45	1·65	1·90	153·0	5·1	152	44·5	43·8	45·3	44·6
May	65·7	42·0	77	28	53·9	3	0·61	0·27	1·67	1·93	244·5	7·9	200	57·6	54·4	56·8	50·2
June	64·0	47·8	74	38	55·9	0	2·18	0·29	2·04	1·63	139·0	4·6	222	59·1	57·0	57·2	54·5
July	68·8	54·0	83	44	61·4	0	4·01	1·30	2·19	2·25	184·6	6·0	208	64·3	62·0	61·6	58·1
August	65·5	50·1	73	41	57·8	0	2·89	0·56	2·19	2·35	163·5	5·3	194	59·5	57·9	59·8	58·7
September	66·1	51·2	77	44	58·7	0	2·56	0·78	1·98	2·18	114·2	3·8	147	59·1	57·4	58·8	57·6
October	56·5	42·5	64	34	49·5	2	1·26	0·35	3·11	2·85	119·7	3·9	105	48·4	49·7	53·3	54·9
November	48·1	36·3	56	19	42·2	15	0·84	0·25	2·79	3·18	65·8	2·2	55	39·9	41·3	45·2	48·7
December	47·2	39·5	56	26	43·4	5	2·97	0·55	2·66	2·48	12·2	0·4	42	41·3	41·7	43·8	45·8
Totals						100	24·69		26·10	26·73	1,469·0		1,563				

Sub-Station, Newlands Farm, Throwley

January	44·2	34·3	51	27	39·3	18	4·67	0·70			67·5	2·2		37·1	38·4	40·3	43·7
February	33·6	22·9	48	11	28·3	28	2·40	0·34			51·9	1·8		33·2	35·2	37·5	41·2
March	48·5	35·6	61	26	42·1	12	0·57	0·20			159·9	5·2		39·7	40·5	40·6	41·0
April	49·8	35·4	65	29	42·6	17	1·05	0·37			169·7	5·7		43·7	44·6	44·7	44·1
May	63·6	43·9	74	34	53·8	4	0·62	0·15			270·3	8·7		55·5	54·1	52·5	48·4
June	61·9	47·7	70	40	54·8	0	2·95	0·56			167·5	5·6		56·8	57·3	56·0	52·7
July	67·1	53·8	81	45	60·5	0	3·09	1·40			186·3	6·0		61·8	61·3	59·7	55·7
August	64·4	49·6	71	42	57·0	0	6·19	2·31			168·2	5·4		58·1	59·6	59·5	57·4
September	65·2	51·5	75	47	58·4	0	2·33	0·65			123·4	4·1		57·9	58·3	57·7	56·5
October	55·0	43·6	62	33	49·3	2	1·28	0·45			121·9	3·9		50·1	52·5	53·9	54·9
November	46·3	37·2	53	24	41·8	13	0·66	0·23			69·1	2·3		42·9	45·1	47·4	50·5
December	46·4	38·4	54	26	42·4	10	4·02	0·73			16·3	0·5		42·4	43·6	45·0	47·3
Totals						104	29·83				1,572·0						

* Weighted averages for 35-year period 1881 1915, as used in the Monthly Weather Report of the Meteorological Office.

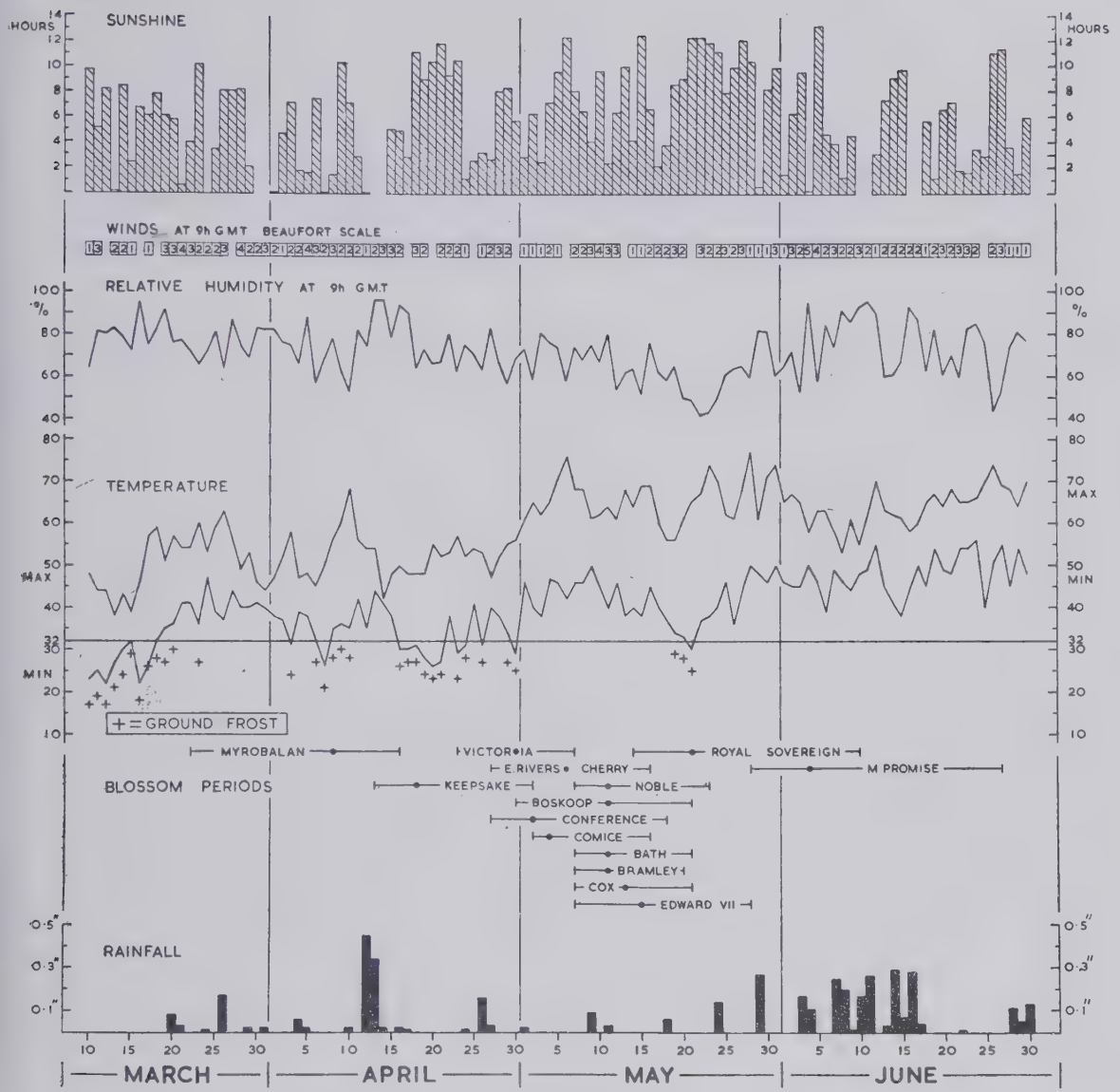

FIG. 1

Diagram showing the weather recorded during the blossoming season at East Malling Research Station in 1956

so that anchorage of the trees was less secure. Strong winds of 'Force 6' or over were recorded 28 times.

Thunderstorms occurred 10 times over or in the neighbourhood of the Station during January, June, July, August, September, and October. Some brought heavy falls of rain and hail, particularly that on 9th July when 1·30 in. of rain fell between 0200 hours and 0900 hours. Larger amounts were recorded in other parts of Kent causing considerable flooding. During a thunderstorm on 6th August, extremely heavy hail caused damage to fruit and crops, especially outdoor tomatoes. Amounts varied over the Station and the neighbouring village, where the hail was more intense, while further afield, in the Tunbridge Wells area, there were exceptionally heavy falls of hail and some snow.

Snow and sleet were recorded 29 times during January, February, March, April, and December; of these 19 were during February when the ground was covered or partly covered for 8 days. Snow was recorded twice during December (on 25th and 26th) for the first time since 1952.

Newlands Farm, Throwley

Rainfall was again higher than at East Malling by 5·14 in., the difference being less than over the past two years. Total sunshine was also higher by 103 hours, March being the only month to have sunshine less than East Malling. The sunniest day of the year was on 25th July, when 14·9 hours were recorded. As in the past, mean maximum temperatures were below those at East Malling, while the mean minima were about the same. The highest temperature recorded was 81° F., on 26th July, and the lowest 11° F., on 21st February. Thunderstorms were recorded 20 times with heavy falls of rain and hail, one on 19th July, when 1·40 in. fell, and the other on 6th August, when 2·31 in. were recorded. Snow and sleet were recorded 34 times, the ground being continuously snow-covered for 10 days from 18th to 27th February. Gale force winds were recorded on a large number of occasions.

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PLANT PHYSIOLOGY

ASPECTS OF ROOTSTOCK PROPAGATION
IV. THE WINTER STORAGE OF HARDWOOD CUTTINGS

By E. S. J. HATCHER* and R. J. GARNER

The hardwood cutting method has always attracted propagators, first because hardwood cuttings are able to survive open ground planting and second because such cuttings have reserves sufficient for rooting whilst the buds are dormant. The method, however, while simple and straightforward has been limited in its practical use in the nursery because of great variability in behaviour of cuttings, and in overcoming this, winter storage treatment of hardwood cuttings seems likely to prove of sufficient promise to encourage its use for a wide range of rootstock varieties.

With selected rootstocks behaviour patterns were determined as the basic stage in a comprehensive factor analysis (Garner and Hatcher, 1955). This showed the benefit of a favourable cutting source and the use of a growth substance. Nevertheless, differences between varieties were not eliminated and the shy rooter was still too precarious a proposition for the rootstock raiser. Then followed experiments in which cuttings were planted in different soils (Hatcher, de Boer, and Garner, 1955), with the conclusion that however favourable the soil, this of itself could not overcome shyness to root.

The idea of storage

As a result of the soil studies, interest was focussed on the possibilities of ' storing ' the cutting through the winter, rather than planting immediately in the autumn. Such storage is normally practised in Holland to avoid the risk of frost-lifting in winter, a risk enhanced by the shallow planting dictated by high soil water table. Under English conditions the value of winter storage seemed to lie in the provision of a more protected environment during the early life of the cutting.

Storage experiments proper began in 1950–51 and for two seasons the storage medium was soil *in situ* (as in Holland), protection being provided by sunk wooden frames with straw covers, with the cuttings inserted in small bundles to rather more than half their length. It was soon realized that conditions in the soil pits could be unfavourable in a wet winter due to water-logging and consequent poor aeration. From 1952–53 this has been avoided by the use of a mixture of equal parts of peat and sand as the storage medium, set over ballast to ensure good drainage.

Recurring observations on stored cuttings showed that a variable seasonal factor was operating. This is well illustrated by rooting data on Brompton plum hedge cuttings over a five-year period (Table I). Basal and second cuttings from the shoot were compared with and without treatment

TABLE I

ROOTING (PERCENTAGE) OVER A FIVE-YEAR PERIOD OF BROMPTON HEDGE CUTTINGS STORED FROM NOVEMBER TO MARCH AND SPRING PLANTED IN OPEN SOIL

Season	Storage medium	Basal		Second	
		No growth substance	IBA dip	No growth substance	IBA dip
1949–50	soil	61	82	78	83
1950–51	soil	22	60	16	66
1951–52	soil	64	96	72	88
1952–53	peat/sand	23	76	8	48
1953–54	peat/sand	68	98	100	93

with a growth substance (quick dip in alcoholic indole-butyric-acid solution, specification ½ mg. IBA per ml. 50 per cent alcohol). These cuttings were taken in November, stored through the winter and planted out in the nursery bed in spring.

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Rooting in 1950–51 and 1952–53 was much poorer than in the other three years, particularly where cuttings were not treated with growth substance, and the overriding effect of soil temperature was soon evident. In Table II the mean soil temperatures at a depth of 8 inches are given, calculated for bi-monthly periods (November–December ; January–February) these together covering the period of winter storage.

TABLE II

MEAN SOIL TEMPERATURE AT 8 INCHES DEPTH EXPRESSED AS FAHRENHEIT DEGREES ABOVE FREEZING POINT DURING FIVE WINTERS

Season	Degrees above freezing point	
	Nov.–Dec.	Jan.–Feb.
1949–50	10·1	7·9
1950–51	6·8	5·7
1951–52	11·0	4·5
1952–53	5·1	4·8
1953–54	13·2	5·5

The temperature-rooting correlation is more particularly a feature of the first two months of storage, which is brought out in Fig. 1 in which percentage rooting is plotted in order of ascending mean temperatures during November and December.

Before considering further the effect of temperature it is useful to examine more precisely the effect of storage itself, choosing the 1953–54 season, when the late autumn soil temperatures were the highest since the present series of experiments began in 1942. Rooting data are included in Table III for the three rootstocks Myrobalan B and Brompton plums and Crab C apple, the cuttings being planted in two different soils, one favourable, the other known to be less suitable for rooting.

All plum cuttings, whether treated with growth substance or not, rooted and established extremely well after winter storage in peat and sand, followed by spring planting in the good soil. The percentage with visible roots at the time of removal from store varied from 0 to 100, indicating that transference may be successfully effected with cuttings at quite widely different stages of development, and that the observed condition at planting is not necessarily a guide to subsequent performance. Immediate autumn planting on the same soil gave a lower but still quite good ' stand ' of cuttings, but on the unsuitable soil rooting was much poorer unless winter storage intervened.

In contrast, treatment of cuttings of the shy-rooting Crab C with growth substance was obligatory, but rooting behaviour on the unsuitable soil was still much impaired even with preliminary storage, though this was of definite benefit. One interesting feature is that rooting in the suitable soil was rather better with direct planting in the autumn than with winter storage, the second cuttings in particular being more checked by the disturbance of transference. This effect was probably one of enhanced sensitivity following heavy treatment with growth substance, as was also the greatly impaired effect in the poorer soil.

The soil temperature effect manifest in the seasonal variability in rooting, so long a puzzling feature of cutting experiments, is noteworthy for two reasons :

(1) At the critical level quite small differences in temperature resulted in quite large differences in rooting, the range in the five years 1949–1954 being only 8° F.

(2) The temperature levels themselves were not unduly high, with the maximum November–December mean being only 45° F.

At higher temperatures roots are produced more rapidly ; to quote an example, in eight weeks Crab C basal hedge cuttings taken in early October and given growth substance rooted 16 per cent in a natural store and 81 per cent in a warm store at 65° F. It is significant, however, that after planting in the nursery bed the eventual establishments of the two groups of cuttings were 53 and 30 per cent respectively, which demonstrates the liability of the highly stimulated cutting to succumb after transference from storage. Reaction of the cutting to warmth, i.e. eight weeks storage at 65° F., was similarly obtained whether the warmth was given immediately after making the cutting or after an initial period without supplementary heat. The effect of such delay worsens the chance of subsequent establishment in the open.

The behaviour of the hardwood cutting depends not only on root formation but also on the transference operation from store to open ground. Experimentally the need was to advance from the variable conditions of the natural store to a form of controlled storage to prevent the temperature in

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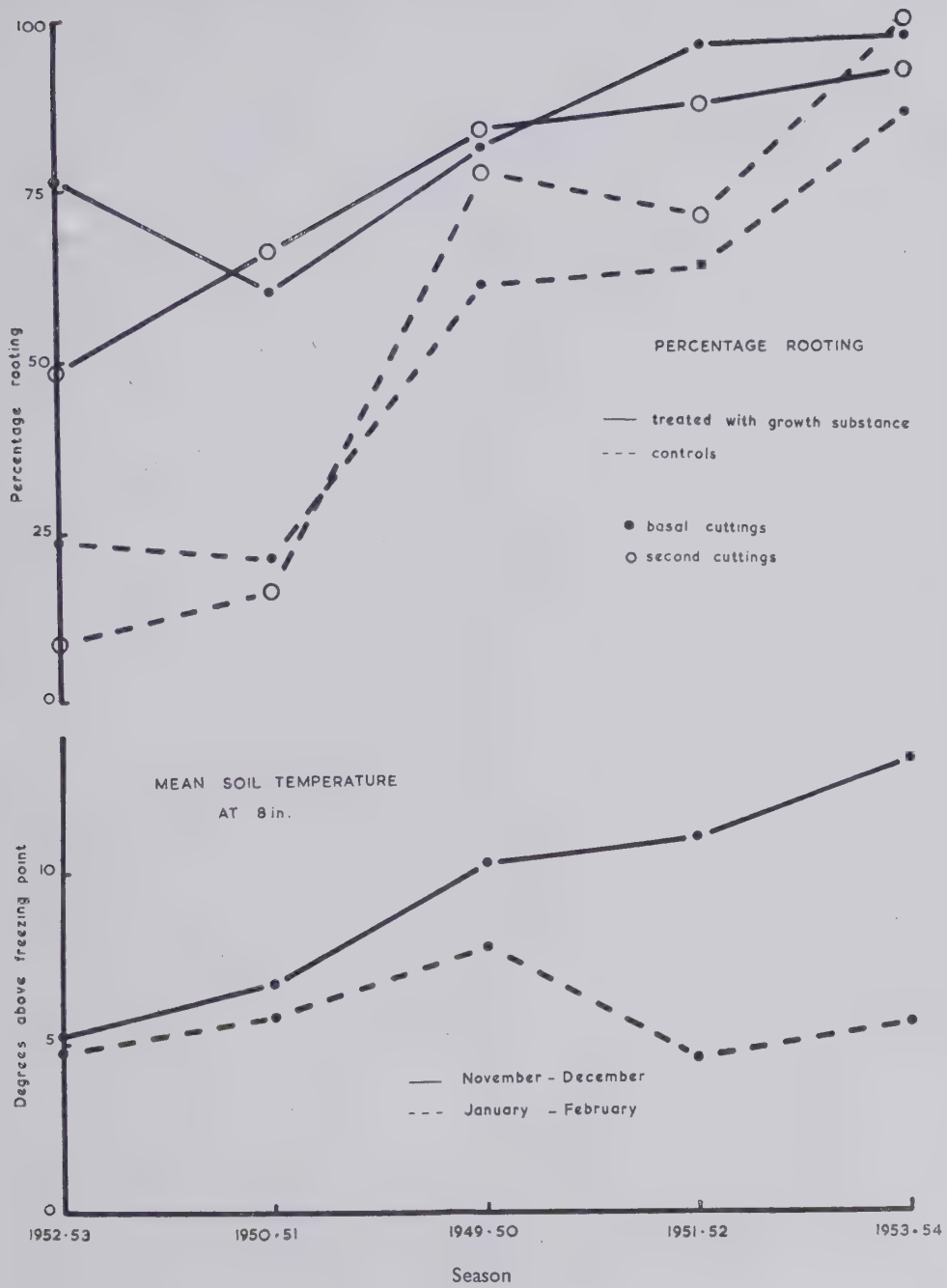

FIG. 1

The relationship between soil temperature and rooting of Brompton plum cuttings

the cutting store falling below a chosen level. This extended the over-all factor analysis to include temperature as a treatment variable, with the emphasis on the interplay of factors (Garner and Hatcher, 1957). Furthermore, the early results have been so encouraging as to demand an extension of this investigation to a much wider range of rootstocks. Present experiments are accordingly both intensive and extensive. In one sense controlled storage has achieved immediate success ; in another it has so deepened experimental enquiry that all previous results must be re-assessed. Hence the need for an appraisal of the new position, and a description of the technique of winter storage with

Table III

Rooting (percentage) of hedge cuttings in two soils with and without previous storage

Soil	Rootstock	Myrobalan B					Brompton					Crab C				
	Winter environment	Basal		Second		Mean	Basal		Second		Mean	Basal		Second		Mean
		O	G	O	G		O	G	O	G		O	G	O	G	
A	Stored	82	95	95	93	*91*	86	98	100	93	*94*	3	72	0	23	*25*
	Not stored	78	83	85	50	*72*	57	83	73	70	*71*	15	80	0	47	*36*
B	Stored	80	97	70	65	*78*	72	65	67	75	*70*	2	48	0	15	*14*
	Not stored	58	68	43	28	*49*	42	73	25	27	*42*	2	20	0	2	*6*

A—Favourable soil.
B—Less favourable soil.

O—No treatment.
G—Treated with growth substance by quick dip.

a discussion of the practical implications, even though the precise temperature needs of the different cuttings are still undetermined.

The technique of storage

The description of the original controlled storage unit at East Malling will form an introduction to the procedure. A general view of the store is shown in the photograph (Fig. 2). It consists of a row of six bins each 4 ft. square, constructed of pre-cast concrete bars 4 ft. × 1 ft. × 2 in., two bars on top of one another to give a height of 2 ft., the whole being slightly sunk in the ground. Support is given by poles and wire guys. Fig. 3 shows a diagrammatic vertical section through one of the bins. At the bottom is a 4-inch layer of coarse gravel to facilitate drainage, over which is the storage medium itself, a 10-inch layer of a mixture of equal parts of peat and coarse sand. To conserve heat the bins are enclosed by bales of straw and further protected with straw-thatched hurdles laid flat across each bin.

Supplementary warmth is supplied electrically, a plan of the installation being shown in Fig. 3. The elements are low-voltage (7·5 v.) galvanized wires of appropriate length (approximately 41 ft. of 12-gauge wire per bin) laid in zig-zag coils in the surface of the gravel and held in position by pegs. The six elements are connected by terminals to copper bus-bars mounted on wooden battens running along the length of the bins, in turn connected to a weatherproof transformer (0·75 K.V.A.) fed from the mains supply. Temperature is controlled by a rod-type thermostat with 30-inch stem inserted in the medium 8 inches below the surface. The thermostat is set to operate at 45° F., so preventing temperature from falling below this level.

The cuttings are stored closely together in rows, not singly but in small groups, set vertically with their bases 8 inches deep in the peat and sand. The capacity of the six bins is over 20,000 cuttings.

In practice, storage is a straightforward technique quite compatible with the basic simplicity of the hardwood cutting method. Once the cuttings are stored little attention need be given, though temperatures must be taken regularly to check that the heating system is functioning effectively. Rain and melting snow percolate through the straw covers and the storage medium of peat and sand is thus kept moist. The straw and warmth attract mice, and traps or rodenticide should be used.

The electrical equipment may be purchased complete and ready for installation from a number of firms who specialize in soil warming. As a guide, a store for 20,000 cuttings would cost under £100 including electrical equipment, pre-cast concrete, and peat and sand. Operation costs are low, and are determined by seasonal conditions. In a mild winter under 500 units of electricity may suffice, though in a severe winter this figure may well be trebled.

Discussion

The practical value of winter storage of hardwood cuttings is beyond question, and for the nurseryman raising rootstocks it promises to bring more varieties within the compass of this attractive method of propagation. The advantages are fourfold : (i) as a cutting ' bank ', (ii) to provide an ideal rooting environment during the early life of the cutting, (iii) as an insurance against deficient soil temperature in a severe winter, and (iv) to supply any special temperature requirements beyond the scope of the natural surroundings.

A cutting ' bank '

Without storage facilities the hardwood cutting must be planted at once ; with storage ' taking ' and ' planting ' become independent operations.

Cuttings must be ' taken ' at a suitable time and a general recommendation would be from late October to mid-November ; but as storing is so simple and rapid the collection of cutting material may proceed more quickly than when immediate planting is involved. In making cuttings it is suggested that those from different regions of the shoot be kept separate, i.e. basal cuttings, second cuttings and so on. The purpose of this is to allow for greater precision of growth substance treatment and to ensure greater uniformity of behaviour.

The cuttings should be removed from store when planting conditions are good ; there is considerable latitude once the cutting has had its initial temperature treatment. As a general recommendation the period late February to late March is suggested, planting first those varieties which leaf out early.

An ideal environment

The most critical time is during the first weeks after making the cutting, when a favourable environment for root formation is essential. In this respect a peat-sand mixture is superior to many

soils. Good conditions of moisture and aeration are particularly necessary to stimulated cuttings whether by temperature and/or growth substance treatment. An accompaniment of storage is a highly favourable physical environment.

An insurance against winter cold

This is the primary reason for storing cuttings under English conditions. In a season with low soil temperatures in November and December even a ready rooting stock such as Myrobalan B plum will root only poorly. With a shy rooting stock such as Crab C, failure is even more certain. By contrast, in a mild late autumn, cuttings of quite difficult subjects may root well. The 1953–54 season was exceptional in this respect, and again in 1954–55 and 1955–56 natural soil temperatures were quite high. With the plum varieties Myrobalan B and Brompton, autumn planting has given good ' stands ' in these years, though with shyer varieties storage has proved highly advantageous. Even natural storage, without supplementary warmth, may if well-sited be several degrees warmer than open nursery soil.

Special temperature requirements

However mild the first half of the storage period, the second half is invariably colder than the control minimum of 45° F., but further trials would be needed to determine whether greater precision can be achieved than using a single temperature minimum throughout storage. One way is to measure the effect of a period of storage above the 45° F. level, varying both the temperature increment and the duration of its application. An interesting observation in this connexion is the great variation in the progress of rooting during storage, both as between different rootstock varieties, and also as between different temperature treatments. This once more raises the question as to the optimal condition of the cutting when transference is made from store to open soil.

The present outlook

The outlook for plum rootstocks is promising ; apart from the varieties Myrobalan B and Brompton already mentioned in the text, St. Julien A and the shy-rooting Pershore have been successfully stored. For plums the growth substance treatment is a dip of $\frac{1}{2}$ mg. IBA per ml. 50 per cent alcohol—the so-called standard dip. In the case of apple rootstocks M.VII as well as Crab C have responded well to treatment where the heavy dip of $2\frac{1}{2}$ mg. IBA per ml. was used.

Acknowledgements

The authors offer sincere thanks to Mr. M. M. MacNeill for much help and guidance in the construction and maintenance of the controlled storage unit.

Summary

A preliminary account is given of the development of a winter storage technique for hardwood cuttings. A temperature controlled storage unit is described and its practical advantages discussed. It is expected that winter storage will enable more rootstock varieties to be raised commercially from hardwood cuttings.

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Fig. 2
Controlled storage unit for hardwood cuttings

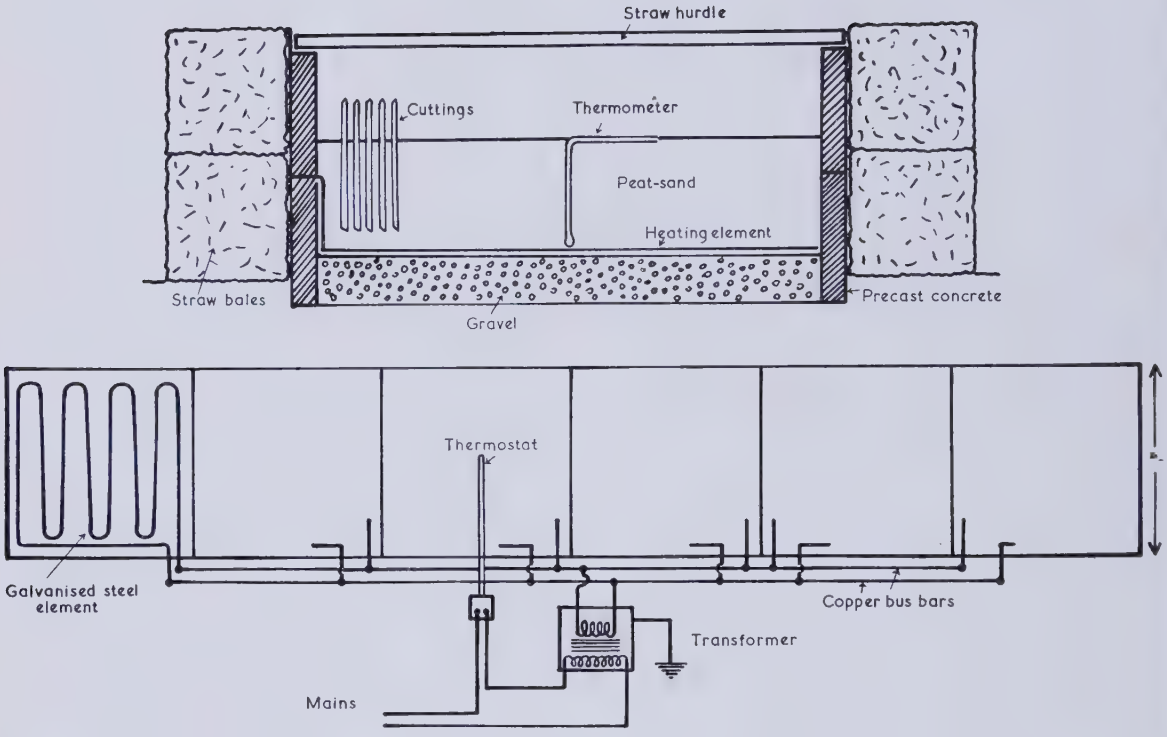

FIG. 3

Upper diagram : Vertical section through storage bin.
Lower diagram : Lay-out of electrical heating system

A PHOTOMETER FOR ESTIMATING THE AREA OF SAMPLES OF DETACHED LEAVES

By D. H. MAGGS

The diminution in light produced by the introduction of leaves between a light source and a photometer has been the basis of several instruments for estimating leaf area. The principal requirements for the method to be successful are :

(1) a constant light source, or a method for compensating for its variation,
(2) uniform illumination of the leafage,
(3) representative sampling by the photometer,
(4) a known and sensitive relation between photometer reading and leaf area.

An instrument has been in use at E.M.R.S. which compensates for variation in source light by measuring the light before, as well as after, passing the leaves, and in which leaf area is measured by withdrawing an opaque screen in exact proportion to the absorption of light by the leaves.

In this instrument (Fig. 1) the light source (S) is a circular fluorescent tube housed in a box 22 inches square and 11 inches high. Alternative sources would be screened 60-watt bulbs in the corners of the box, or direct illumination by a battery of 6-volt bulbs (Milthorpe, 1942). The light is further diffused by a sheet of double reeded glass (D) placed, corrugated side uppermost, 9 inches above the light source and 1 inch below the leaf sample. Such a glass gives better scattering than ground glass. After passing the leaves, the residual light enters the mixing chamber and is sampled by the photometer receptor. This is a barrier-layer selenium cell lying face-upward on a sheet of ground glass fitted across the mixing chamber. The photometer consists of two parts : (1) the light measuring system, consisting of the receptor photocell (P), a balancing photocell (P_2) and a galvanometer sensitive to 0·1 micro-amps with variable shunt, and (2) the system for translating light intensities into area, consisting of a movable opaque screen (MS) in the same plane as the leaves which can vary the light reaching the receptor, and a mechanism to measure movements of the screen. The screen is moved by a finely pitched lead-screw driven by a reversing motor (RM), and its movement is measured by a revolution counter (RC) on the lead-screw. The travel of the screen is restricted by limit switches at each end of its traverse. All reflecting surfaces are painted matt white.

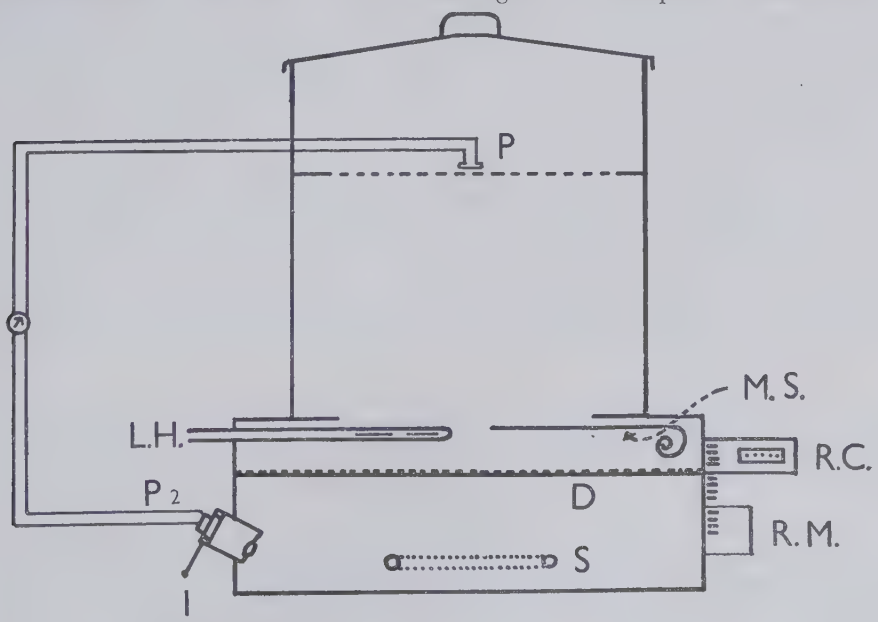

FIG. 1

Diagram of the instrument.

D. = double reeded glass. I. = iris diaphragm. L.H. = leaf holder. M.S. = movable screen. P. = receptor photocell. P_2 = compensating photocell. R.C. = revolution counter. R.M. = reversing motor. S = light source

The photometer works as follows. Before leaves are introduced, the currents from the two photocells are balanced against each other, and adjusted by means of an iris diaphragm (I) in front of P_2 to bring the galvanometer to zero, the shunt being used when the currents are far out of balance ; final adjustments can be made with the moving screen, which should be nearly fully extended. The revolution counter is set to zero and the leaves are introduced in a glass holder (LH). The consequent darkening registered by the receptor is nullified by rolling back the screen until the galvanometer again reads zero. The screen movement is recorded by the number of revolutions of the lead-screw, and would give a direct measure of the leaf area if the leaves were as opaque as the screen. In practice, the instrument is calibrated directly in terms of leaf area by measuring leaf samples of known area made by cutting round an accurate template placed over a pile of 5–10 leaves.

The use of two balancing photocells allows the use of the galvanometer at maximum sensitivity and automatically compensates for variation in intensity of the light. Bolas and Melville (1933) have shown that in a similar balanced system, the source light can vary by 25 per cent without seriously affecting results. Where it is impracticable to use photocells and a galvanometer, it should be feasible to adapt the apparatus so as to compare the two samples of light visually, as in the Bunsen grease-spot photometer—and at the other extreme it could be made automatic by using the current from the photocells to control the movement of the reversing motor.

Accuracy of observations

Estimates have been made of errors arising from various sources in operating the machine. Different operators have obtained results in very close agreement. Random variation in the photometer produces a standard deviation of $\pm$ 1 sq. cm. in the individual reading, irrespective of the sample size, which can be from 1 sq. cm. to the maximum input of 400 sq. cm. Any errors resulting if the light is not uniformly distributed over leaves and moving screen are minimized by spacing the leaves evenly in the holder, and by putting in approximately the same amount of leafage each time. The correction factor required to convert revolutions of the lead-screw to area in sq. cm. increases curvilinearly with calibrated sample size, becoming practically constant at areas larger than 100 sq. cm.

Sampling errors are more complex, depending on the number of replicates of both main samples and calibrated subsamples. For example, the estimated total leaf area of a tree equals the product of calibrated area times revolutions for sample/revolutions for calibrated area times total leafage/sample leafage. Total leafage/sample leafage may be estimated in terms of leaf weight or number.

It has been shown that if there are N main sample replicates and n calibrated sample replicates, as N + n is always in practice limited, e.g. by time, errors are minimized if N and n are in the ratio of about 3 : 2. In much of the work for which this instrument has been used, one calibration subsample is taken from each sample, so that N = n, and the significant differences for various numbers of samples are as follows ($p = 0{\cdot}05$) :

N	1	2	3	4	5	10
per cent difference	11	8	6	5	5	3

Thus the area of foliage from two trees will be significantly different, if, based on two samplings from each, the estimated total area of the one is 8 per cent more than that of the other.

Acknowledgements

Mr. K. Bunyard was largely responsible for constructing the instrument, and Mr. G. M. Jolly of the Statistics Section gave much assistance with the sampling methods.

Summary

An instrument is described which estimates photo-electrically the area of 100–400 sq. cm. of detached leaves. Its accuracy is assessed.

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MEASUREMENTS OF EXPERIMENTALLY INDUCED COPPER DAMAGE IN APPLE LEAVES

By F. W. M. LLEWELYN*

A method of measuring the ' leaf scorch ' produced experimentally on raspberry leaves, based on determinations of the water content of the leaves, was described by Llewelyn and Allen (1952). The present paper describes the application of the method to apple leaves, and gives the results of an investigation of the relationship between the amount of scorch, the concentration of the copper sulphate solution employed as the damaging agent, and the time of year when the solution is applied.

Method

The work was carried out on a stool-bed of M.II rootstocks, which provided a hedge of upright stems, renewed each year. Owing to the toxic nature of the solution, it was necessary to avoid damaging any leaves other than those whose scorch it was desired to measure. For this reason, and also on account of the variability involved in spraying leaves, each individual leaf was dipped momentarily in the solution and then allowed to drain dry as if it had been sprayed to ' run-off '. The length of time for immersion was the least possible consistent with all the air bubbles escaping from the leaf surface, and rarely exceeded five seconds. All the solutions contained 0·05 per cent dioctyl sodium sulphosuccinate as a wetter. On the third day after the leaves had been dipped, each lamina was weighed to the nearest 0·005 g. and the dry weight determined after desiccation in an oven at approximately 98° C. for an hour or more.

The use of these data as measures of leaf scorch depends upon a suitable choice of damaging solution, the preparation of proper control leaves, the use of sufficiently large samples, and adequate randomization of the treatments. The scorch produced by a given solution is measured by comparing the fresh weight/dry weight ratio of leaves dipped in that solution with the ratios for both undamaged and completely scorched leaves, all three samples of leaves being under similar conditions of water supply and relative humidity throughout. The detailed method of calculation is given by Llewelyn and Allen (1952). To satisfy these conditions in the field, stems were selected at such a spacing that the solution dripping from the leaves of one stem would not affect another. These stems were labelled in numerical order along the row, the label being fastened immediately below the sixth expanded leaf from the apex. Sufficient stems were chosen to enable each solution to be applied to at least five stems ; in later experiments six replicates were used. Treatments were assigned to the stem number at random within blocks of stems, the blocks providing replicates of the treatments along the row. On each stem the three leaves above the label were dipped in the solution appropriate to that stem's number. Three days later, the stems were cut off the plants and brought into the laboratory where the laminae of the leaves were weighed separately and the amount of damage calculated.

The aim was to relate the damage obtained, or a function thereof, to the concentration of the solution applied. The treatments applied included both a sample of undipped control leaves showing only such damage as the leaves had already suffered before the experiment began, and a sample of leaves dipped in a solution known from experience to give complete scorching of the entire lamina ; for this purpose a 3 per cent solution of ammonium thiocyanate has been found to be satisfactory.

Results

During 1955, a series of experiments was carried out on one stool-bed to determine how the response of the plant varied throughout the season to concentrations of copper sulphate. It was soon found that the relation between the empirical probit of the percentage of the leaf scorched and the logarithm of the percentage concentration applied was very close to a straight line. Examples of these are shown in Fig. 1, the dates indicating when the leaves were dipped. The equations correspond to the best fitting straight line shown, and the figure in brackets is the percentage concentration of copper sulphate (pentahydrate) calculated from these equations to give scorch of half the leaf tissue (i.e. the LD50). There can be little doubt that a straight line is a satisfactory description of these results, and that the slopes and intercepts are significantly different on the occasions. Similar straight lines were obtained on other dates, their equations and the LD50 being given in Table I.

These results show that the susceptibility of apple rootstock leaves to copper sulphate damage varies in a complicated fashion throughout the season, many small changes occurring within short

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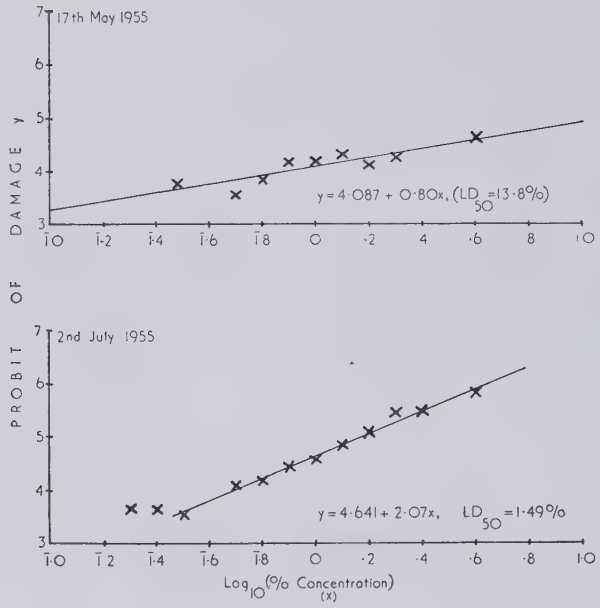

FIG. 1

Examples of linear relations between copper sulphate concentration and the leaf scorch produced on M.II apple leaves

TABLE I

THE RELATIONS BETWEEN THE PROBIT OF PERCENTAGE LEAF SCORCH (Y) OF M.II APPLE LEAVES AND THE LOG. PERCENTAGE CONCENTRATION OF COPPER SULPHATE APPLIED (X) THROUGHOUT THE SEASON 1955

Date of application	Equation of best straight line	Concentration to give 50% scorch (LD50)
17th May	$Y = 4\cdot09 + 0\cdot80x$	13·8%
23rd ,,	$Y = 4\cdot76 + 1\cdot32x$	1·52%
17th June	$Y = 5\cdot16 + 3\cdot52x$	0·90%
2nd July	$Y = 4\cdot64 + 2\cdot07x$	1·49%
8th ,,	$Y = 4\cdot72 + 2\cdot13x$	1·35%
14th ,,	$Y = 4\cdot90 + 1\cdot54x$	1·16%
22nd ,,	$Y = 5\cdot70 + 2\cdot10x$	0·46%
2nd August	$Y = 5\cdot76 + 2\cdot79x$	0·54%
12th ,,	$Y = 5\cdot15 + 2\cdot78x$	0·88%
24th ,,	$Y = 4\cdot78 + 1\cdot99x$	1·29%
30th September	$Y = 4\cdot71 + 1\cdot20x$	1·74%

The brackets embrace equations whose slopes or LD50s are not significantly different and are adjacent in time.

periods of time, the most important change being from the relatively insensitive state shown on 17th May to the sensitivity found on 23rd May and subsequently.

To determine what effect, if any, the interval between treating the leaves and measuring their fresh weights would have on the measurement of the damage, a series of leaves was treated as described above on 31st May, half of them being weighed on 3rd June and the rest on 6th June. As might have been expected, the water content of the untreated controls differed significantly between the two occasions, their fresh weight/dry weight ratios being 2·76 on 3rd June and 2·50 on 6th June. The completely killed leaves treated with ammonium thiocyanate showed a smaller change, from 1·19 to 1·14 respectively. No attempt was therefore made to pool the ratios for the two harvests since the same ratio in the two harvests could represent different amounts of damage. The proportion of leaf scorched was calculated independently for each sample (Table II).

TABLE II

THE EFFECT OF DELAY IN HARVESTING, AFTER APPLICATION OF COPPER SULPHATE SOLUTION, ON THE DAMAGE MEASURED

	Concentration of copper sulphate (percentages)									
	0·16	0·30	0·50	0·80	1·0	1·6	2·5	4·0	6·3	10·0
Percentage scorch after 3 days	4·5	15·8	13·9	12·1	28·4	76·5	80·8	82·2	93·2	91·9
Percentage scorch after 6 days	0	8·1	11·3	17·4	41·9	75·8	91·5	86·3	92·0	91·0

These percentages, excluding those for the lowest concentration, were converted to empirical probits. Statistical analysis showed no significant difference between harvests, but there was a highly significant deviation from linearity in the regression of probit damage on log. per cent concentration. This result is shown in Fig. 2 where the three lines all have slopes significantly greater than zero.

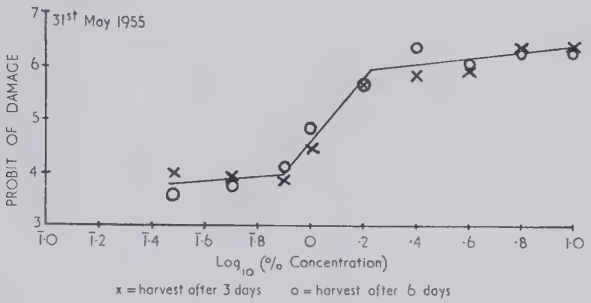

FIG. 2

The effect of delay in harvesting scorched leaves on the measurement of their damage

This test begun on the 31st May, gave the first definite indication that a single straight line would not always suffice to describe the response of this stool-bed to copper sulphate ; further tests during the year also showed large departures from linearity. The dates when these occurred and the deviations from the straight line are shown on the graphs of Fig. 3. No significant differences could be found between the two results obtained on 7th and 10th June when the two straight lines shown on each graph were fitted to the data, and the slope of the lower of the two lines, despite its very low value, was still significantly greater than zero.

Discussion

When apple leaves are dipped in copper sulphate solution momentarily, and then allowed to drain dry, they very shortly show dark brown spots on the lower epidermis scattered at random over the surface and not restricted to the veins or interveinal areas. This effect may become apparent within an hour after treatment on a warm day. At higher concentrations the spots are larger and they coalesce and appear on the upper surface also. After a week in this condition, during which time the brown spots lose water even though the leaf as a whole has remained turgid, the edges of the leaf begin to turn brown, and a continuous brown area gradually spreads from the edge into the leaf along the interveinal areas. The final stage is the abscission of the leaf, unless so strong a solution of copper sulphate was used that it killed the abscission layer. It is not yet known what is the minimum concentration of copper sulphate necessary to bring about this secondary effect. In the results given above the damage measured is the initial damage seen as random spotting, and changes in the susceptibility of the plant as shown by these measurements must be ascribed to the condition of the plant at the time of application of the solution, subsequent weather conditions having no effect.

It is not the purpose of this paper to discuss the reasons for the changes in susceptibility throughout the season indicated by these results, but merely to show, by quantitative methods, the variation in response detected after as short a time as is practicable following the application of the poison.

An important feature of the results is the change in slope of the regression lines of probit damage on log. concentration. This renders any determination of the damage caused by a single concentration

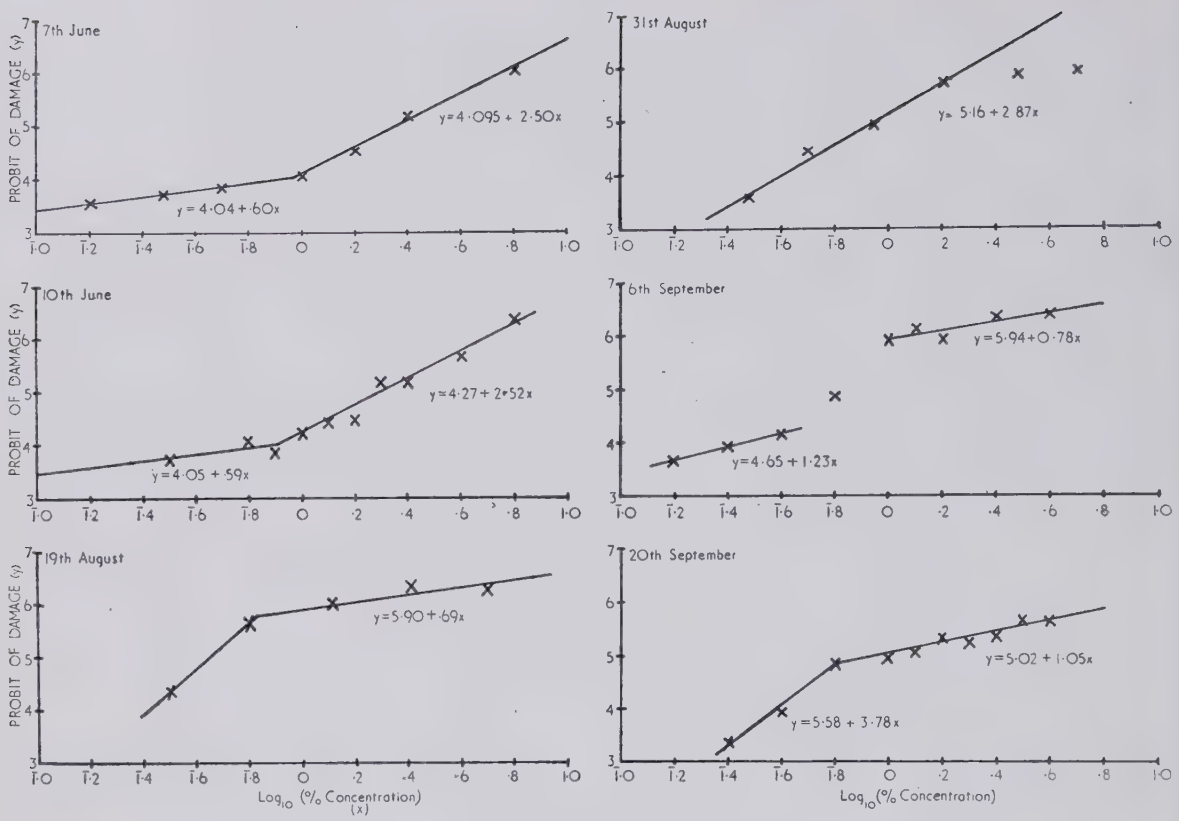

FIG. 3

Examples of non-linear relations between copper sulphate concentration and leaf scorch produced on M.II apple leaves in 1955

of a poison useless as a basis for discussion about its effect at other concentrations. Thus it might be expected that since, from Table I, a 13·8 per cent solution of copper sulphate on 17th May and a 0·90 per cent solution on 17th June were needed to cause the same damage, then less damage would be caused by a 0·30 per cent solution in May than in June. In fact, however, this concentration gave less damage in June (7·15 per cent) than in May (11·4 per cent.).

The breaks in the line on any one occasion (Figs. 2 and 3) render the task of assessing the action of the copper sulphate even more difficult than had the response been linear, for a determination of the shape of the graph, when linearity cannot be expected, must depend upon estimating the position of a large number of points. Since there are physical limitations to the size of the experiment, these points must be estimated from smaller samples than when only a few points need to be found. The positions of the breaks in the curve can therefore be found in an uncertain manner either by a few widely spaced points each of high precision, the uncertainty arising from the interpolation between the points, or from a large number of closely spaced points each suffering from greater random variation due to the smaller number of fresh weight/dry weight ratios from which they were calculated. An example of the first method is shown in Fig. 2 where the damage done by 1·0 per cent copper sulphate (log. conc. = 0) shows a significant deviation from the lower line but is of little use in showing how the lower joins with the upper. Examples of the second method are shown in Fig. 3 for 10th June and 6th September where the uneven spacing of the log. concentrations was due partly to a desire to crowd the points around the suspected breaks and partly to the variation in the fresh weight/dry weight ratios giving results outside the 0–100 per cent range of damage. The importance of the breaks lies in their interpretation as indicating changes in the mechanism of action of the solution. Further work is being carried out in an attempt to induce similar breaks and changes in slope in the response curve in order to obtain a greater insight into the reasons for variations in spray damage.

Difficulties of technique, mentioned in the previous paper, resulting from the spread of damage from treated to untreated leaves have been overcome by using a stool-bed of plants instead of attempting to crowd all the treatments and replicates on one tree. With the M.II rootstocks used on this plot

no damage spread from a treated stem along the plant to another stem, although neighbouring stems occasionally suffered from accidental splashing of the leaves. The worst spread of damage with copper sulphate has been with the concentrations above 1·0 per cent and with these, when it occurs at all, the damage only appears on leaves above those that have been treated. The possibility mentioned in the previous paper, of abolishing the completely killed control leaves and making the assumption that the data fit a straight line must clearly be abandoned, and all tests must include the two calibrating samples of undamaged and completely scorched leaves.

Summary

A quantitative method of measuring the scorch experimentally induced on leaves of an apple rootstock is described. Results are presented of an investigation into the relation between the damage done and the concentration of copper sulphate solution applied to the leaves, the complex changes in the relationship throughout the season of 1955 being given in detail.

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BUFFER CAPACITY AND pH OF TISSUE FLUIDS OF LEAVES OF SULPHUR-RESISTANT AND SULPHUR-SHY VARIETIES OF APPLE *(PYRUS MALUS* L.) AND GOOSEBERRY *(RIBES GROSSULARIA* L.)

By F. M. TURRELL* and LINNA E. BENTLEY†

Elemental sulphur applied to foliage and fruit of citrus is metabolized to sulphate (Turrell and Chervenak, 1949 ; Turrell, 1950). Penetration of citrus tissue by elemental sulphur results usually in lowering the pH of the tissue fluids (Turrell, 1950). Sessions (1936) showed that the pH of tissue fluids of leaves from potato and bean plants was high and these plants were readily injured by sulphur (' sulphur shy '), whereas the pH of tissue fluids from apple and peach leaves was low and these plants were not readily injured by sulphur (' sulphur resistant ').

Sessions (1936) theorized that in plants having tissue fluids of low pH little or no injury would occur as a result of oxidation of sulphur ' since the isoelectric or precipitation point of the protein of such a plant would undoubtedly be at a low pH ', but in tissue fluids of high pH (near neutral) a slight decrease in pH resulting from oxidized sulphur places the protein at or near its isoelectric point and results in tissue injury. He recognized, too, that the capacity to maintain a given tissue-fluid pH, or the buffer capacity of the plant, might be a decisive factor in protein precipitation, regardless of the native pH of the tissue fluid.

Turrell and Storherr (1951) have shown that the peel-tissue fluid of lemon has a higher pH than that of orange, and that the buffer index (β) of lemon fruit peel-tissue fluid is smaller than that of orange. Turrell and Scott (1951) have shown that the buffer index of citrus leaves is larger than that of orange peel. The sensitivity of lemon fruit and the resistance of orange fruit and citrus leaves to sulphur injury have long been recognized.

In 1949 and 1950 Turrell and Chervenak published radioautographs that showed a reaction of lemon peel proteins with elemental radioactive sulphur dusted on whole lemon fruit, but it was not clear whether the reaction with the protein occurred first, resulting in the liberation of sulphate to the tissue fluids, or whether the production of large amounts of sulphate occurred first, followed by its reaction with the peel protein. Knowledge of the relation between pH and buffer capacity of tissue fluids of sulphur-shy and sulphur-resistant varieties of plants would aid in determining this question.

Preliminary work on sulphur-resistant and sulphur-shy varieties of muskmelons was undertaken by the senior author in the United States of America, but since both apples and gooseberries of sulphur resistant and shy varieties were available at the East Malling Research Station, Kent, England, growing under identical climatic conditions and in nearly identical soil conditions, a very critical test of the relation of pH, buffer capacity, and sulphur shyness seemed possible there. Through the courtesy of the East Malling Research Station, facilities were made available, and this study was initiated during the summer of 1951, while the senior author was on sabbatical leave in England.

Materials and methods

Leaves were collected separately from each of six trees, two of the sulphur-resistant variety Worcester Pearmain and two each of the two sulphur-shy varieties Stirling Castle and Lane's Prince Albert (Taylor, 1948). Rootstock influences sulphur shyness (Preston, Moore, and Bennett, 1951). All varieties were on the Malling rootstock, M.III. Worcester Pearmain had an intermediate stem-piece of Bramley's Seedling, Stirling Castle one of Lane's Prince Albert, and Lane's Prince Albert one of Worcester Pearmain. The same two trees of each variety were used for all collections of samples, the samples varying as to date of picking and as to location of leaves on the branches. Tip leaves (usually the three terminal leaves) of the extension growth of the growing shoot (Fig. 1, D), middle leaves from the central region of the extension growth (Fig. 1, E), and leaves from spurs located on the older wood (Fig. 1, F) of the branch were selected at random from all sides of the trees at a height of 3 to 7 ft. above ground. Samples of apple leaves were picked fresh as needed, between 2nd July and 16th August, 1951, for pH and buffer-capacity determinations, and on 28th August for the organic acid analyses.

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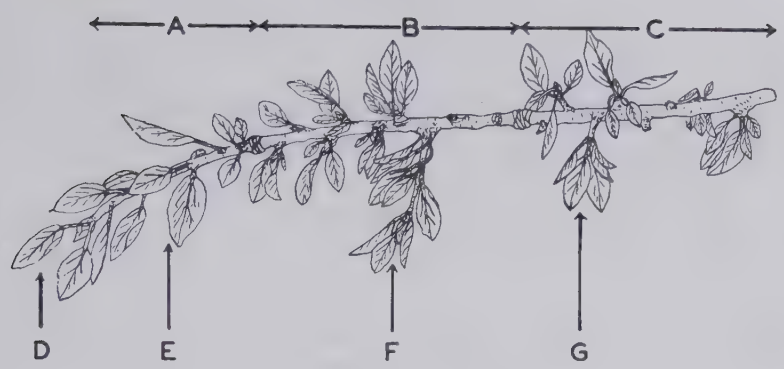


FIG. 1

Diagrammatic drawing of apple branch, showing sources of leaf samples : A, extension growth ; B, first-season wood ; C, second-season wood ; D, terminal or tip leaves of extension growth ; E, middle leaves of extension growth ; F, spur leaves ; and G, leaves on older wood

Leaves from the terminal 3 in. of the green portions of growing stems of two varieties of gooseberries, the sulphur-resistant Keepsake and the sulphur-shy Leveller (Crane and Lawrence, 1934), on Keepsake, and Leveller rootstocks, respectively, were picked on 24th August, 1951, for pH and buffer-capacity determinations. All the leaves from the green stem tips of 19 plants of Keepsake and 9 plants of Leveller constituted the two samples. On 10th June, 1955, leaves for organic acid analyses were collected from the same plants, with the exception of a few which had been pulled out.

Measurement of pH and buffer capacity

The leaf samples were placed in a refrigerator for cooling, within an hour after the first leaves were picked. Later, after they had been cleaned, the leaf blades and petioles were pressed tightly into an ice-cube tray equipped with a tight-fitting aluminium or galvanized-iron cover. They were then frozen at $-5°$ to $-10°$ C. and held in this state until ready for use.

After thawing, the leaf samples were packed into washed sailcloth in a nickel-plated cylinder, and the cell-tissue fluids were pressed from the leaves with a hydraulic jack. The leaf-tissue fluids or expressates so obtained were centrifuged 5 minutes at 2,400 r.p.m., and 25 ml. of the cleared expressate was pipetted into the beaker of a pH-stirring-titration assembly. The expressate pH was determined, and volumes of 0·1000 N hydrochloric acid or 0·1000 N sodium hydroxide were added to effect pH-unit changes of 0·25 after initial titration to the nearest 0·25 unit. The buffer capacity was calculated as the buffer index, β (Van Slyke, 1922).

Measurements of pH were made continuously throughout the titration with a Muirhead A.C. line-operated instrument equipped with a dip-type glass electrode and calomel half-cell assembly.

Organic acid determination

Six grams of fresh tip leaves of Lane's Prince Albert and Worcester Pearmain apples and of Leveller and Keepsake gooseberries were boiled 5 minutes in distilled water containing 1 ml. of normal H_2SO_4. The mixture was ground in a mortar and centrifuged. The apple-leaf extract was concentrated to a known volume of about 6 ml., and the gooseberry-leaf extract to 9 ml. These were applied directly to Whatman No. 1 filter paper. Unidimensional descending chromatograms were made, using the alcoholic phase of a solution composed of tertiary amyl alcohol 80 : chloroform 80 : 90 per cent formic acid 30 : with 80 parts water as a solvent. The chromatograms were dried for 6 hours at room temperature and sprayed with 0·04 per cent aqueous bromocresol green adjusted to pH 10. No attempt was made to identify acids present in concentrations of less than 0·5 mg./g. fresh weight of tissue (Bentley, 1952).

The quantities of citric and malic acid were determined from the chromatograms by the spot-area method (Paech and Tracey, 1955), in which concentration is determined by comparison of the sample spot area with a linear semilogarithmic curve of spot areas of various organic acid concentrations. This method yields results that are accurate to ± 10 per cent (Paech and Tracey, 1955 ; Bentley, 1953).

Isocitric acid was identified in the presence of citric acid which has the same R_f value, by partial conversion to isocitric lactone on boiling an aliquot of the extract for 30 minutes. Citric acid was also determined in the apple-leaf extracts by the pentabromoacetone method (Pucher, Vickery, and Leavenworth, 1934).

Results

pH of apple leaves

In sulphur-resistant apple varieties only tip leaves (Fig. 1, D) and basal leaves of extension growths appear to be sulphur shy ; middle leaves on such growths (Fig. 1, E) are more resistant (Moore, 1948). In sulphur-shy varieties all the foliage may become bleached (Tydeman, 1941 ; Moore, 1948 ; Taylor, 1948), although spur leaves (Fig. 1, F) and leaves on older wood (Fig. 1, G) have been observed to be resistant.

In the light of Sessions' (1936) theory all the tip leaves of sulphur shy varieties would be expected to have a higher native expressate pH than spur leaves. It will be noted in Table I that the tip and

TABLE I

NATIVE pH AND ACID AND BASE BUFFER INDICES IN SEVERAL pH RANGES FOR BLADE EXPRESSATES, AND PETIOLE EXPRESSATES OF LEAVES FROM VARIOUS LOCATIONS ON SULPHUR-SHY AND SULPHUR-RESISTANT VARIETIES OF APPLE TREES

Variety and leaf type	Sampling date	Native pH	Titrant	Buffer Indices* pH 6·00–5·75	pH 5·75–5·50	pH 5·50–5·25	pH 5·25–5·00
SULPHUR SHY							
Lane's Prince Albert							
Blades :							
Spur	8 Aug.	5·53	HCl	—	0·032	0·037	0·047
Spur	8 Aug.	5·80	HCl	0·034	0·032	0·043	0·062
Spur	8 Aug.	5·73	NaOH	0·022	0·024	—	—
Spur	8 Aug.	5·39	NaOH	0·017	0·026	0·029	—
Mean		5·58					
Tip	16 Aug.	5·74	HCl	—	—	0·034	0·041
Stirling Castle							
Blades :							
Spur	2 July	5·15	HCl	—	—	—	0·027
Spur	2 July	5·10	HCl	—	—	—	0·117
Spur	2 July	4·89	HCl	—	—	—	0·068
Spur	2 July	5·03	NaOH	0·020	0·027	0·038	0·054
Mean		5·03					
Middle	25 July	5·42	HCl	—	—	0·068	0·102
Middle	25 July	5·82	HCl	—	—	0·012	0·063
Middle	25 July	5·54	HCl	—	—	0·017	0·035
Middle	25 July	5·68	HCl	—	0·022	0·013	0·043
Middle	25 July	5·40	HCl	—	—	0·300	0·042
Middle	25 July	5·69	NaOH	0·024	—	—	—
Middle	25 July	5·55	NaOH	0·019	0·020	—	—
Mean		5·56					
Tip	16 Aug.	5·38	HCl	—	—	0·075	0·079
SULPHUR RESISTANT							
Worcester Pearmain							
Blades :							
Spur	2 July	5·13	HCl	—	—	—	0·048
Spur	2 July	5·08	HCl	—	—	—	0·062
Spur	2 July	5·15	NaOH	0·020	0·024	0·033	0·032
Mean		5·07					
Spur	8 Aug.	5·70	HCl	—	0·030	0·036	0·053
Spur	8 Aug.	5·70	NaOH	0·022	0·024	—	—
Mean		5·70					
Middle	25 July	5·73	HCl	—	—	0·022	0·039
Middle	25 July	5·38	HCl	—	—	0·018	0·021
Middle	25 July	5·28	HCl	—	—	0·039	0·040
Middle	25 July	5·58	NaOH	0·020	—	—	—
Middle	25 July	5·28	NaOH	0·018	0·016	0·020	—
Mean		5·42					
Tip	16 Aug.	5·35	HCl	—	—	0·040	0·035

TABLE I (*continued*)

Variety and leaf type	Sampling date	Native pH	Titrant	Buffer Indices* pH 6·00–5·75	pH 5·75–5·50	pH 5·50–5·25	pH 5·25–5·00
SULPHUR SHY							
Lane's Prince Albert							
Petioles :							
Spur	8 Aug.	5·45	HCl	—	—	0·035	0·045
Tip	16 Aug.	5·52	HCl	—	0·130	—	0·024
Stirling Castle							
Petioles :							
Middle	25 July	6·00	HCl	0·023	0·029	0·028	0·040
Middle	25 July	5·50	NaOH	0·010	—	—	—
Mean		5·68					
Tip	16 Aug.	5·73	NaOH	0·005	0·030	—	—
SULPHUR RESISTANT							
Worcester Pearmain							
Petioles :							
Spur	8 Aug.	5·50	HCl	—	—	0·037	0·055
Middle	25 July	5·48	HCl	—	—	0·017	0·021

* For successive acid titrations (from native pH), read from left to right ; for base titrations, read from right to left.

middle leaves of Stirling Castle have a higher pH than the spur leaves, as expected by theory. This pH difference is highly significant statistically. Tip leaves of Lane's Prince Albert also have a higher pH than spur leaves, as expected by theory.

If the pH of tip and middle leaves of the sulphur-shy varieties as a group is compared with the pH of a group composed of sulphur-resistant leaves—that is, of spur leaves of sulphur-shy varieties and all leaves of the sulphur-resistant variety—the pH is significantly higher, statistically, in the sulphur-shy leaves. This tends to confirm Sessions' theory.

Leaf and fruit abscission is characteristic of sulphur-shy varieties (Tydeman, 1941 ; Taylor, 1948 ; Moore, 1948). Abscission occurs through chemical and structural changes and breakage in a very limited zone of the petiole and pedicel. A number of measurements on expressates from whole petioles are shown in Table I. It can be seen that the pH is higher in the petiole expressates of the sulphur-shy leaves from sulphur-shy varieties. These results tend to confirm Sessions' theory, but they are not significant statistically.

Acid β-indices of apple leaves

Sessions has suggested that a high buffer capacity in cell-tissue fluids is associated with resistance to sulphur damage. It is necessary to assume that such buffer capacity must be effective very close to the native pH of the cell-tissue fluid. Thus, if the buffer indices (β) obtained by the first addition of acid to the expressates of spur leaves of sulphur-shy varieties and leaves from all locations in the sulphur-resistant variety are taken as a group and compared with β for the tip and middle leaves of the sulphur-shy variety, the buffer capacity of the sulphur-resistant leaves will be noted to be larger than that of the sulphur-shy leaves (Table I), but the difference is not statistically significant. Also the correlation ($r = -0{\cdot}325 \pm 0{\cdot}205$) between native pH and buffer-index is low and negative and not statistically significant. The buffer-index decreased as the leaves aged (Fig. 15).

pH of gooseberry leaves

The pH of leaf expressates of the sulphur-shy Leveller gooseberry and of the sulphur-resistant Keepsake variety showed that the pH was higher in the sulphur-shy variety (Table II), and the difference is statistically highly significant. Thus, Sessions' theory is confirmed for these two varieties of gooseberries.

Acid β-indices of gooseberry leaves

The first acid-buffer indices of leaf expressates were smaller in the sulphur-shy Leveller gooseberry than in the sulphur-resistant Keepsake variety (Table II), and the difference is statistically significant. Sessions' theory, again, is confirmed in the gooseberry.

The negative correlation between native pH of the leaf expressate and buffer capacity seen in apple leaves is quite apparent in gooseberry leaves. However, in gooseberries the correlation is high, and significant at the 5 per cent level ($r = -0.958 \pm 0.00474$).

Organic acids in apple leaves

Malic, citric, isocitric, and succinic acids were identified in the acidulated water extracts of tip leaves of Lane's Prince Albert and Worcester Pearmain apple varieties. The concentrations of citric, isocitric, succinic acids, and an unidentified acid having the R_f of quinic acid (probably derived from the depside of caffeic and quinic acid, chlorogenic acid, found in apples by Bradfield *et al.*, 1952) in both the sulphur-shy and the sulphur-resistant varieties are approximately the same (Table III). But the malic acid in the sulphur-shy variety was approximately twice the concentration of that in

TABLE II

NATIVE pH AND ACID AND BASE BUFFER INDICES IN SEVERAL pH RANGES FOR EXPRESSATES OF LEAVES FROM EXTENSION GROWTHS OF SULPHUR-SHY AND SULPHUR-RESISTANT VARIETIES OF GOOSEBERRY BUSHES

Variety and leaf type	Native pH	Titrant	Buffer Indices*			
			pH 5·00–4·75	pH 4·75–4·50	pH 4·50–4·25	pH 4·25–4·00
SULPHUR SHY						
Leveller						
Tip	4·79	HCl	0·042	0·045	0·044	0·057
Tip	4·84	HCl	0·033	0·042	0·047	0·057
Tip	4·87	NaOH	0·023	—	—	—
Mean	4·83					
SULPHUR RESISTANT						
Keepsake						
Tip	4·31	HCl	—	—	0·089	0·065
Tip	4·30	HCl	—	—	0·102	0·062
Tip	4·36	NaOH	0·028	0·046	0·061	—
Mean	4·32					

* For successive acid titrations (from native pH), read from left to eight ; for base titrations, from right to left.

the Worcester Pearmain (Table III). The ratios of the buffer indices of leaf expressates of leaves picked the same week confirm the presence of acids in these relative concentrations.

The buffer-index curves of apple-blade and petiole expressates, shown in Figs. 2 to 7, when compared with buffer curves of standard malic and citric acids are similar in the range of pH 4·6 to 6. However, in most of the expressate curves there is about as great an increase in β per unit pH change below pH 4·6 as above. Since the slope of the buffer-index curves of standard malate and citrate combined declines somewhat below pH 4·6, the increasing β of leaf-expressates probably results from the presence of the unidentified organic acid which in tip leaves was found in concentrations somewhat lower than the malic acid concentration in Lane's Prince Albert. However, our estimate of quinic acid concentration is subject to considerable error because of its low R_f. In fact, if the unknown acid is quinic acid or its isomers, it would require in some cases five times the concentration found to explain the steep slope of some of the acid buffer-index curves below pH 4·6, even though the pH of quinic acid may be close to that of chlorogenic acid which has a pH of 3·5 (Ingraham and Corse, 1951).

Spur leaf-blades of Lane's Prince Albert appear to contain slightly less (Fig. 3) to substantially more of the unidentified acid than those of Worcester Pearmain (Fig. 6), while the spur leaf-petioles of Lane's Prince Albert contain much less than those of Worcester Pearmain (Fig. 7). The leaf-blade

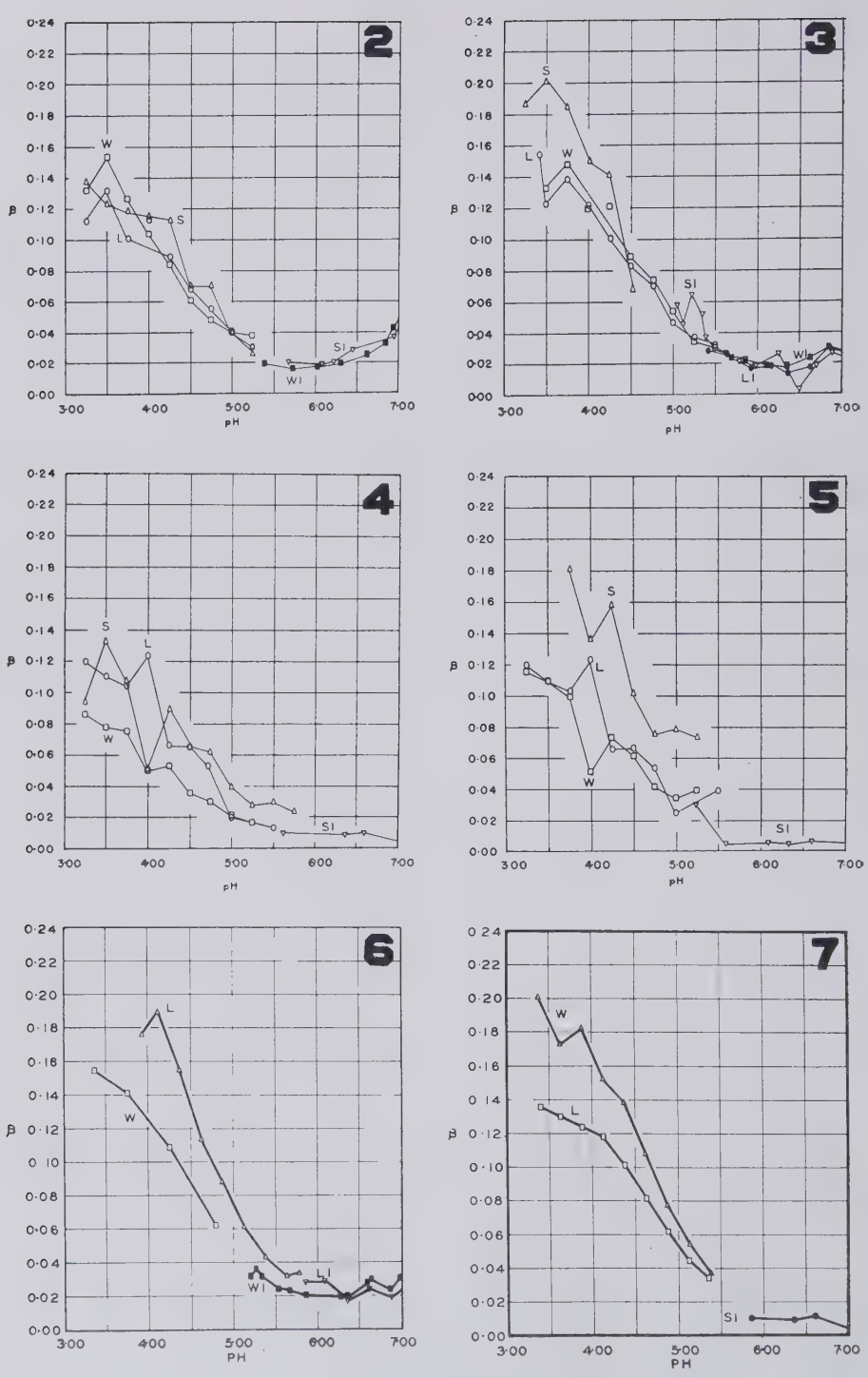
Table III

Total organic acid content of acid water extracts of tip leaves of sulphur-shy and sulphur-resistant varieties of apples and gooseberries (Mg. per g. fresh weight)

Variety and sample no.	Citric and isocitric (R_f=0·26)	Pentabrom-citric	Isocitric lactone (R_f=0·46)	Glutamic (R_f=0·09)	Malic (R_f=0·37)	Succinic (R_f=0·68)	Unidentified (R_f=0·11)
Sulphur shy							
Lane's Prince Albert apple							
1	—*	1·2	Trace	None	4·4	Trace	In quantity
2	2·6	—	do.	do.	6·2	do.	do.
3	—	1·8	do.	do.	5·2	do.	do.
4	—	3·9	do.	do.	6·2	do.	do.
5	1·9	2·2	do.	do.	4·4	do.	do.
Mean	2·25	2·27			5·28		
Leveller gooseberry							
4	2·15	—	None	Trace	0·76	Trace	Trace
5	2·35	—	do.	do.	1·49	do.	do.
6	2·75	—	do.	do.	1·66	do.	do.
6a	2·60	—	do.	do.	1·60	do.	do.
7	2·34	—	do.	do.	0·75	do.	do.
9	3·22	—	do.	do.	0·58	do.	do.
Mean	2·58				1·14		
Sulphur resistant							
Worcester Pearmain apple							
1	—	2·4	Trace	None	2·8	Trace	In quantity
2	2·1	—	do.	do.	2·7	do.	do.
3	—	1·9	do.	do.	—	do.	do.
4	2·6	3·3	do.	do.	—	do.	do.
5	1·9	1·9	do.	do.	2·9	do.	do.
Mean	2·2	2·37			2·8		
Keepsake gooseberry							
1	1·89	—	None	Trace	0·71	Trace	Trace
2	1·91	—	do.	do.	1·02	do.	do.
3	1·84	—	do.	do.	0·61	do.	do.
5 + 8	1·99	—	do.	do.	1·02	do.	do.
X_1†	1·65	—	do.	do.	0·79	do.	do.
X_2†	1·98	—	do.	do.	0·82	do.	do.
Mean	1·88				0·83		

* Dash indicates no analysis.

† X_1 and X_2 = composite samples of several bushes, nos. 9 to 19.



FIGS. 2–7

Buffer-index curves (HCl and NaOH) of expressed tissue fluids of apple leaf blades and petioles, showing change in buffer capacity (β) with pH of fluid : HCl, Worcester Pearmain (W), Stirling Castle (S), and Lane's Prince Albert (L) ; NaOH, Stirling Castle (S-1) and Worcester Pearmain (W-1). Fig. 2.—Blades of middle leaves (S, W and S-1 and W-1) and tip leaves (L). Fig. 3.—Blades of spur leaves. Fig. 4.—Petioles of middle (S, W, S-1) and tip leaves (L). Fig. 5.—Blades (S, W) and petioles (L, S-1) of tip leaves. Fig. 6.—Blades of spur leaves. Fig. 7.—Petioles of spur leaves (L, W) and middle leaves (S-1)

curve of Worcester (Fig. 6) and the leaf-petiole curve of Lane's more nearly approximate the β curve of standard citrate and malate.

Organic acids in gooseberry leaves

The total organic acid content of gooseberry leaves extracted with acidulated water is shown in Table III. In the sulphur-resistant Keepsake variety, there is a little less than half the citric and malic acid contained in the sulphur-shy Leveller variety. Quinic acid concentration is about the same in both varieties and is approximately of the same concentration as citric acid of the Keepsake variety. Quinic acid, judging by the buffer curves, does not appear to be a major organic acid constituent in gooseberry leaves. Thus the relation between the organic acid concentrations in sulphur-shy and sulphur-resistant leaves is about the same in both apples and gooseberries. The acid-buffer-index curves of gooseberry leaves indicate by their shape (Fig. 8) that citric and malic acids are the predominant acids present, and the organic acid analyses confirm this.

Acid and base titrations

Buffer-index and titration curves for apple and gooseberry leaves do not appear to be available. Acid-buffer-index curves are presented in Figs. 2 to 7 for apples, and in Figs. 8 and 9 for gooseberries. Comparison of the shapes of the acid β-index curves against curves of standard organic acids here shown to be present, shows that the buffer systems active near native tissue-fluid pH in apples and gooseberries are primarily citrates and malates. The base-buffer-index curves suggest the presence of a phosphate buffer, as most of the apple-leaf expressates showed no bicarbonate peak at pH 6·4, but a peak at pH 6·8 (Figs. 2 to 7). On the other hand, the gooseberry base-buffer-index curves (Fig. 9) show no peaks either at pH 6·4 or at pH 6·8. It is noteworthy that the sulphur-resistant variety of gooseberry has a very large β for both acids and bases near the native pH of the leaf-tissue fluid.

The acid and base titration curves for apple and gooseberry leaf expressates shown in Figs. 10 to 14 appear to be regular and normal in every respect, and thus lend assurance of the reliability of the β-index curves.

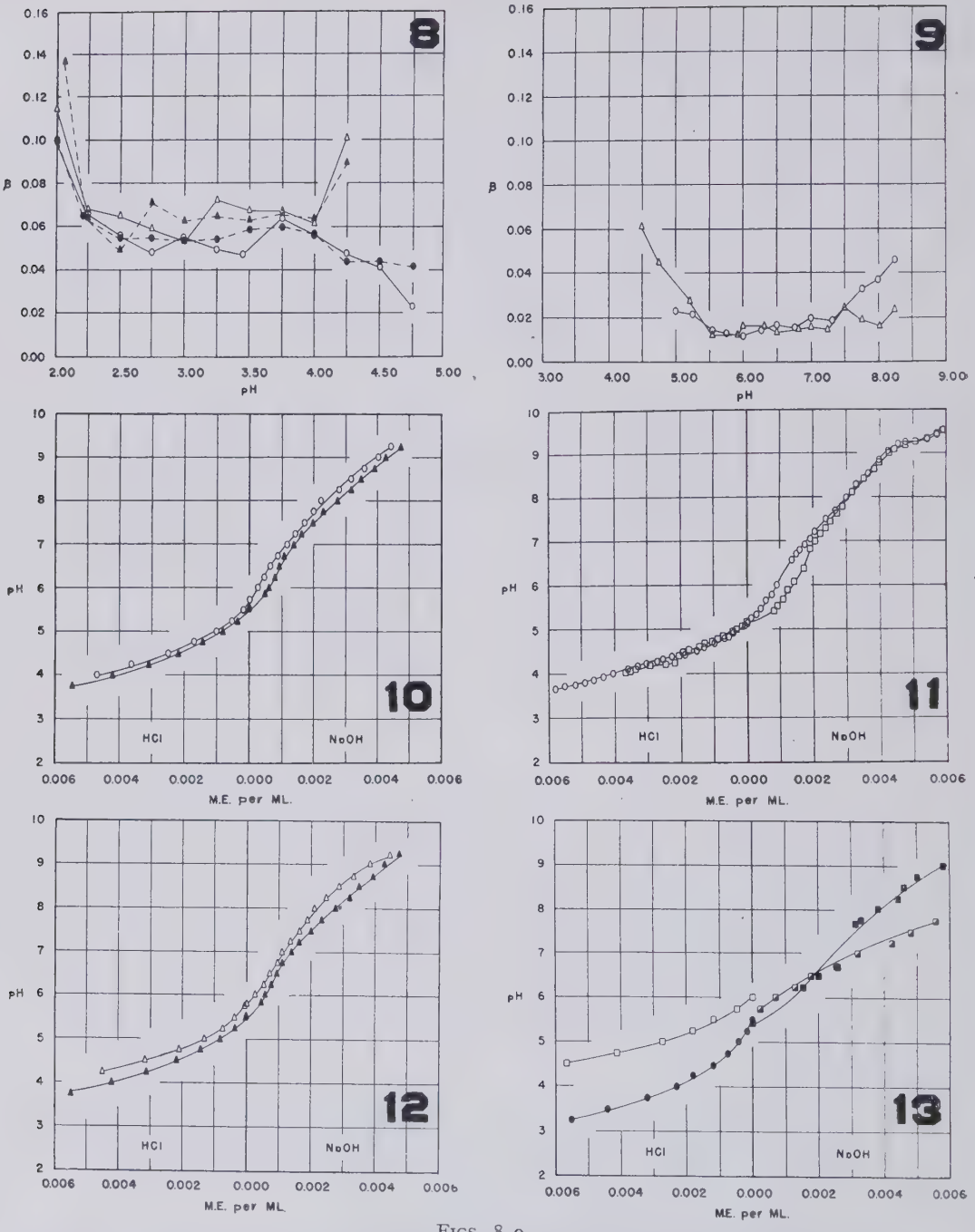
Expressate pH and sampling date

Analyses were made on apple leaves picked on four different dates over a period of about one month ; gooseberry leaves were picked on one date only. The significant difference found between sulphur-resistant and sulphur-shy varieties of gooseberries suggests that sampling date may have played a role in the variability of pH and initial acid-buffer-index in the apple leaves. This is confirmed for hydrogen-ion concentration and the days which elapsed from first sampling to subsequent sampling dates, by the moderately high and highly significant negative correlation coefficients when leaves from all locations are included (Stirling Castle, $r = -0{\cdot}754 \pm 0{\cdot}130$; Worcester Pearmain, $r = -0{\cdot}787 \pm 0{\cdot}120$; Stirling Castle, Worcester Pearmain, and Lane's Prince Albert as a population, $r = -0{\cdot}776 \pm 0{\cdot}0795$). But the correlation between days elapsed between initial and subsequent sampling dates and the initial HCl β-indices was low and not significant ($r = -0{\cdot}367 \pm 0{\cdot}204$) ; this might be expected because of the nature of the buffer mechanism. The above correlations show that the hydrogen-ion concentration in the leaf expressates declined, or the pH increased, as the season progressed (Fig. 15).

The increase in pH with the age of the leaves suggests that the organic acids are neutralized as the age of the leaves increases. Sodium, calcium, and potassium usually are the principal cations concerned. Brown (1927) showed that for apple fruits a good negative correlation existed between hydrogen-ion concentration and total ash ($r = -0{\cdot}4949$). Therefore, the high organic acid content and high pH of sulphur-shy leaves of sulphur-shy varieties suggest that such leaves must contain relatively higher concentrations of the salts of the organic acids. This condition probably places the buffer action in a pH range where its effectiveness is low.

Summary

In leaves of apple and gooseberry varieties sulphur shyness (susceptibility) has been found to be correlated with high pH and low buffer capacity in expressed leaf-tissue fluids, which confirms Sessions' theory. These correlations suggest accelerated SO_4-formation prior to protein injury. In apple leaves buffer capacity appears to play a less significant role than in gooseberry leaves. The principal buffers are malic, citric, and possibly chlorogenic acids and their salts in apple leaves, and citric and malic acids and their salts in gooseberry leaves. Buffer capacity declines and pH increases in apple leaves with age.



FIGS. 8–9

Buffer-index curves (HCl and NaOH) of expressed tissue fluids of gooseberry tip leaf blades and petioles combined, showing change in buffer capacity (β) with pH of fluid. Fig. 8.—HCl, Keepsake (two upper curves) and Leveller (two lower curves). Fig. 9.—NaOH, Keepsake (triangles) and Leveller (circles)

FIGS. 10–13

Titration curves (HCl and NaOH) of expressed tissue fluids of apple leaf blades and petioles, showing change in pH with number of milliequivalents (m.e.) of reactant added per millilitre of expressed tissue fluid. Fig. 10.—Blades of spur leaves of Worcester Pearmain (upper curve) and Lane's Prince Albert (lower curve). Fig. 11.—Blades of spur leaves of Worcester Pearmain (upper curve) and Stirling Castle (lower curve). Fig. 12.—Blades of spur leaves of Lane's Prince Albert, tree 2 (upper curve) and tree 1 (lower curve). Fig. 13.—HCl, petioles of middle leaves: Stirling Castle, tree 1 (upper curve); Worcester Pearmain, trees 1 and 2 (lower curve); NaOH, petioles of middle leaves: Stirling Castle, tree 2 (upper curve), trees 1 and 2 (lower curve)

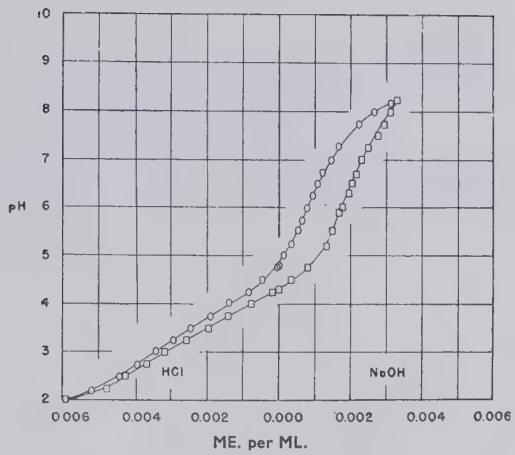


FIG. 14

Titration curves (HCl and NaOH) of expressed tissue fluids of gooseberry tip leaf blades and petioles (combined), showing change in pH with the number of milliequivalents (m.e.) of reactant added per millilitre of expressed tissue fluid : Leveller (upper curve) and Keepsake (lower curve)

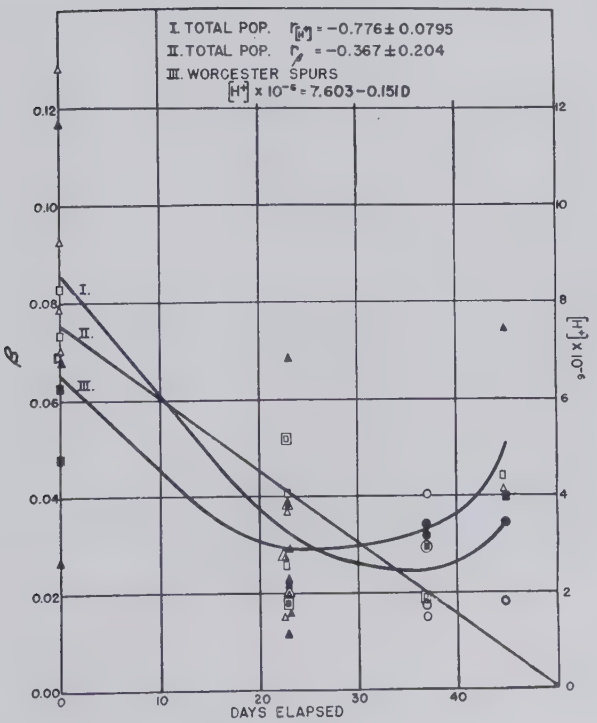


FIG. 15

Decline in β-indices (solid symbols) and in hydrogen-ion concentration ([H+]) (open symbols) of expressed tissue fluids of apple leaf blades with days elapsed from initial picking date to subsequent picking dates

Acknowledgements

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PLANT PATHOLOGY

A CULTURE TECHNIQUE FOR *VENTURIA* SPP. AND A TURBIDIMETRIC METHOD FOR THE ESTIMATION OF COMPARATIVE SPORULATION*

By D. S. KIRKHAM

A successful infection of apple and pear by *Venturia inaequalis* and *V. pirina*, the causal fungi of apple and pear scab respectively, culminates in the development of sporulating lesions on the surfaces of leaves and fruit. Sporulation in culture may therefore be a highly relevant observation in a study of these facultative parasites. Miller (1949), using agar-slope cultures, obtained objective measures of sporulation and concluded that inoculum concentrations greater than 200,000 conidia per ml. had little effect on the final yield of conidia. Montgomery and Moore (1937) grew cultures of *V. inaequalis* on sterilized apple twigs from which the bark had been removed. They obtained rapid growth and sporulation, and could remove most of the conidia easily, without disintegration of the substrate, by shaking the cultures with water. In the following methods the advantages of a firm substrate have been coupled with the use of media of known or constant composition for the studies of comparative sporulation under various nutritional conditions, and for the provision of routine supplies of conidia for fungicide bio-assay.

Culture technique

The cultures are grown on filter paper cylinders standing in nutrient solutions (Fig. 1). Whatman 541 filter paper is cut into rectangles of a size to produce, when rolled, cylinders of convenient length and diameter. These cylinders are then slipped into and held centrally by stainless steel rings. The dimensions used by the writer are 4·5 × 3·5 cm. rectangles, rolled into cylinders 4·5 cm. long, and held by stainless steel rings as follows : OD $\frac{5}{16}$ in., thickness $\frac{1}{64}$ in. and width $\frac{1}{32}$ in. The cylinders are placed in 6 × $\frac{1}{2}$ in. B.S.S. standard test tubes and heat sterilized before addition of nutrients. Culture media at *p*H 5·6 (e.g. 10 per cent malt extract as suggested by Miller, 1949) are sterilized by filtration and 1 ml. aliquots are then dispensed aseptically into each tube.

Fourteen days before conidia of *V. inaequalis* are required as inoculum, transfers are made from master slopes under paraffin oil to paper cylinders in 10 per cent malt extract. 10 per cent malt extract agar slopes are used for *V. pirina* as, owing to low sporulation, a more concentrated inoculum can be obtained, including mycelial fragments, by gently rubbing the slopes with a rubber-covered glass rod. Inoculum suspensions are prepared in sterile glass-distilled water. Each suspension is strained through fine organdie muslin into a 5 × $\frac{1}{2}$ in. test tube packed, with cotton wool, inside a 6 × 1 in. boiling tube as shown in Fig. 2. After filtration the muslin is removed and the plug of the outer tube replaced. Filtration is necessary owing to the otherwise inevitable blockage of pipettes, used for dispensing inoculum, by large mycelial fragments. Inoculum concentration is adjusted visually to an approximate turbidity of 0·1 (see below), which is equivalent to 2–300,000 conidia per ml. No attempt has been made to wash the suspensions before use owing to possible deleterious effects on spore germination and the very low level of contamination by nutrients from the inoculum cultures which is the same in all tests. Each tube is inoculated with a volume of suspension calculated as sufficient just to cover the paper cylinder (0·2 ml. for the dimensions given above) and the tube is shaken and rotated to ensure even distribution. The cultures are incubated horizontally for 14–21 days at 18° C. They may be killed by the addition of two drops of formalin and stored at 5° C. to await estimation of sporulation.

Estimation of comparative sporulation

Comparative sporulation is determined by turbidimetric estimation of suspensions prepared from each culture. Cultures of *V. inaequalis* are shaken vigorously for one minute with distilled water (6 ml.) and those of *V. pirina* gently for the same time. Vigorous shaking of the latter is undesirable as they produce comparatively few conidia, and the strongly segmented subaerial mycelium tends to

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disintegrate. Each spore suspension is strained through one thickness of fine organdie muslin into a 6 × 1 in. boiling tube. The process is repeated using a further 6 ml. of distilled water and gentle shaking. This treatment yields 10–12 ml. of suspension, containing 95-99 per cent of the conidia and a few small fragments of mycelium. Each suspension is centrifuged at 2,000 rev./min. and the supernatant liquid replaced by distilled water ; this is repeated until no trace of colour remains in the liquid, in order to avoid interference with the turbidimetric estimation. The final spore deposit is resuspended in either 1 or 10 ml. of distilled water, depending on its magnitude, and the suspension stored at 5° C. in the presence of formalin, to prevent microbial deterioration.

The turbidity of each suspension is recorded using a Hilger Photoelectric Absorptiometer (Spekker) with neutral filters and cells of 1 cm. path length, microcells being used for the 1 ml. suspensions. An examination of the relationship between dilutions of a concentrated spore suspension and turbidity, showed it to be almost linear over the range of drum readings 0·02–0·3, but beyond this range there was an increasing departure from linearity (Fig. 3). Concentrated 10 ml. suspensions are therefore adjusted

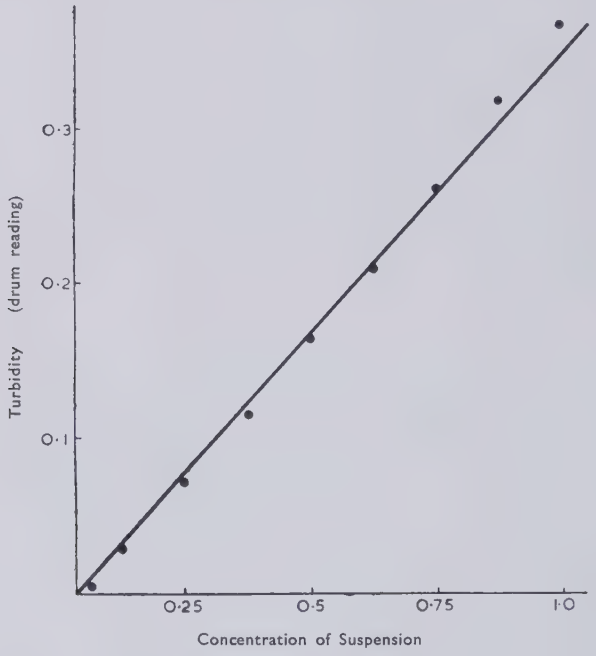

FIG. 3

Linear relationship between dilutions of a concentrated spore suspension and turbidity

by dilution to give readings in the 0·02–0·3 range and the necessary corrections applied to give directly comparable estimates of spore production by the cultures. Readings below 0·02 cannot be accurately determined and 1 ml. suspensions are therefore prepared, the observed drum readings being divided by 10 to obtain results comparable with those of the 10 ml. suspensions. All results are expressed as comparable turbidities.

Advantages of the methods

Venturia spp. usually grow slowly in liquid culture and often produce few conidia ; solid culture media seem to be essential for rapid sporulation. The present culture technique provides a suitable substrate, the nutritional status of which can be easily varied, and avoids the use of unknown factors such as agar-agar. Very small volumes of culture media are required which may be easily filter sterilized, thus permitting the use of thermolabile and rare compounds in studies of nutrition and sporulation. Rapid sporulation occurs on 10 per cent malt extract solution and the method is therefore also well suited to the provision of conidia for fungicide bio-assay.

Unlike cheesecloth wicks (Palmiter, 1934) the paper cylinders are standard in shape and area. Thus, replicate cultures shaken with the same volume of water yield spore suspensions of the same optical density when all other factors are constant. Turbidimetric estimation of comparative sporulation avoids time consuming spore counts.

Fig. 1

Filter paper cylinders standing in nutrient solutions before and after growth of *Venturia inaequalis* ($\times \frac{5}{6}$)

Fig. 2

Apparatus for the aseptic removal of large mycelial fragments from inoculum suspensions ($\times \frac{5}{8}$)

[*face page 126*

Summary

Methods are described for raising sporulating cultures of *Venturia* species and for the turbidimetric estimation of comparative sporulation under various nutritional conditions. The culture method is well suited to the provision of routine supplies of conidia for fungicide bio-assay.

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WHITBREAD'S GOLDING VARIETY HOP: A NOTE ON WILT TOLERANCE IN THE FIELD AND THE ESTABLISHMENT OF A *VERTICILLIUM*-FREE PLANTING STOCK

By J. F. WILSON

Before the initiation of the present Wye–East Malling Breeding Scheme in 1950 the search for Wilt-tolerant varieties of hop was made among the common commercial varieties, the large range of new varieties bred by Professor Salmon at Wye College, a smaller range bred at East Malling Research Station, and a few other varieties bred on a commercial farm (Keyworth, 1947). One of the latter, believed to be an open-pollinated seedling of Bates's Brewer, was bred in 1911 on what is now the Beltring farm of Messrs. Whitbread and Co., and was known as variety '1147'. When the farm became affected by progressive Wilt a planting of this variety was observed to remain productive in a garden in which other varieties had succumbed. Intensive testing confirmed a degree of tolerance comparable with that of Keyworth's Mid-season (OR55) and Keyworth's Early (OJ47), varieties now known to be adequately tolerant under a wide range of field conditions (Keyworth, Hitchcock and Goode, 1953). Records by Messrs. Whitbread of plantings subsequently made to reclaim infected land on the same farm indicated that tolerance was well maintained throughout the farm. These plantings had reached approximately 70 acres by 1953.

Wide interest in the variety was aroused following the annual walk of the Association of Growers of the New Varieties of Hops held at Beltring in August, 1952, and was doubtless stimulated by the rejection of Keyworth's Mid-season by the brewing industry. In response to this demand Messrs. Whitbread generously agreed to release the variety for cultivation by growers in the progressive Wilt area and it was therefore extensively planted from 1954 onwards. The sole source of planting material at this time was the Beltring farm, where it was propagated on infected land. Under the terms of the Progressive Verticillium Wilt of Hops Order, 1953, this stock could only be moved under licence for planting on infected land, but even so the total acreage of the variety had increased by 1956 to approximately 417, and in that year it was named Whitbread's Golding Variety. The allocation of the limited supplies of stock was made by the Propagation Committee of the Hops Marketing Board in co-operation with the Ministry of Agriculture.

The contribution of East Malling Research Station to the introduction of the variety consisted firstly of an assessment of the variety's Wilt tolerance under a wide range of field conditions, and secondly, of the production of a nucleus of planting stock shown by test to be free from the progressive Wilt fungus and with minimal infection by virus diseases (Harris, 1954). A brief description of this work follows.

Survey of wilt tolerance in different localities

Four farms were selected on which the variety was planted in a compact plot and where continuity of the records was not likely to be upset by future layering. These were in various localities and this afforded a range of variation in environmental conditions, particularly in respect of soil conditions, the aspect of environment of most importance in soil-borne fungus diseases. The incidence of the disease in these plots was recorded in 1954, 1955 and 1956 and the results are shown in Table I.

TABLE I

WILT INCIDENCE IN WHITBREAD'S GOLDING VARIETY ON FOUR FARMS, 1954–1956

Locality of farm	Previous cropping	Number of plants	Per cent Wilt		
			1954	1955	1956
Collier Street	Fuggle	309	10·4	Grubbed	—
Five Oak Green	Fuggle	321	6·5	5·9	1·2
Frittenden	OR55	316	Nil	Nil	Nil
Staplehurst	Arable crops for three years	294	1·4	1·1	2·0

A comparison of records made at Collier Street and Five Oak Green with those made at Staplehurst confirms the experience of Messrs. Whitbread and previous experience with other tolerant varieties that planting on infected land immediately following sensitive varieties results in a considerably higher incidence of Wilt than where the land is ' fallowed ' first, but that hills showing Wilt become less numerous in subsequent years (Five Oak Green records). It should be noted that when tolerant varieties are planted immediately after sensitive ones the presence of rogue (' ground keeper ') bines may give a false impression of reduced Wilt tolerance in the new variety in the early years of replanting, and it is thought that this factor may have contributed in part to the figures given for the Five Oak Green farm. Conversely, on some sites a tolerant variety planted immediately after wilted Fuggles has shown a *very low* incidence of Wilt—in some cases none at all—so that no explanation of the absence of Wilt on the Frittenden plot following OR55 can yet be put forward.

The observations made in the four gardens suggest that in respect of Wilt tolerance under commercial conditions the variety is likely to behave in essentially the same way as OR55.

Establishment of a *Verticillium*-free planting stock

Strap cuts were supplied by Messrs. Whitbread from their original planting of the variety, and propagation and testing followed the sequence shown in Fig. 1. The cuts (A) were grown on in a nursery bed on clean land for one season (B). Lateral shoots from these plants were rooted singly in small pots of cutting compost the same season (C). These were taken from at least 2 ft. above soil level as a precaution against possible invasion of the lower part of the bine by *Verticillium* from the root. Dormancy of the resulting small plants was delayed until the following February, by using heat and artificial illumination, to allow the development of substantial root systems. After the onset of dormancy and a period of hardening-off, the plants were put out on land remote from the site of *Verticillium* experiments and with a previous cropping history considered unlikely to have fostered the development or survival of *Verticillium* sp. in the soil. In July the plants were layered (D) and the layers were lifted and cut the following winter.

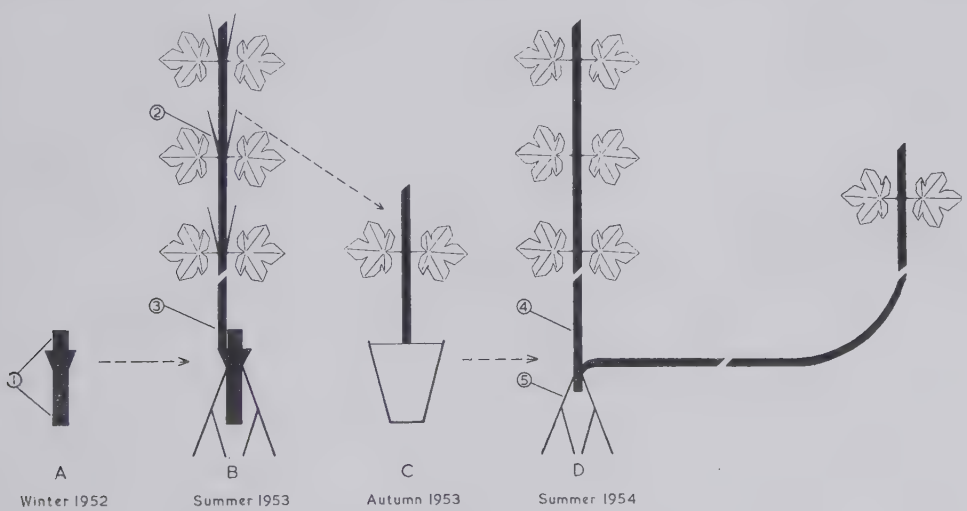

FIG. 1

Diagram showing stages in production of Verticillium-free clone

Isolation tests were made on the five separate occasions shown in the figure. Test (1) was made immediately before planting the original cuts in the nursery bed, by incubating complete transverse sections from the base and top of the cuts, after surface sterilization in 0·1 per cent mercuric chloride, and using the petri dish moist chamber method (Keyworth, 1951). Test (2) was made by the same method on the bases of the lateral shoots before potting them. At the end of the same season, test (3) was made on the bases of all bines from which lateral shoots had been rooted, by plating out complete transverse sections on prune-lactose-yeast agar containing 0·5 per cent potassium thiocyanate. Tests (4) and (5) were made on bine and root respectively after lifting the layers, using the same method as for test (3). *Verticillium* was positively identified in the first test only, and all cuts thus shown to be infected were immediately discarded from the nursery bed. It should be noted that the petri dish moist chamber method occasionally results in the incubated material becoming overgrown by irrelevant contaminant organisms some of which may be similar to *Verticillium* spp. Cuts thus

regarded as of ' doubtful ' infection status were destroyed. Similarly, in test (2) a number of ' doubtful ' laterals were discarded from the rooting frame.

Layer cuts were thus produced from plants tested for the presence of *Verticillium* at three stages in their production, the parent plants themselves having been selected from source material tested twice for freedom from *Verticillium*. It was therefore assumed that the layer cuts were themselves *Verticillium*-free, and in 1955 they were grown into sets on fresh land similar to that on which the layer bed was established. A random sample of the source plants had in the meantime been virus tested by grafting to indicator plants. This testing showed the new stock to be a carrier of Mosaic, to be free from Nettlehead and apparently free from the more severe forms of Split Leaf Blotch. At the end of the year these sets were made available to the Propagation Committee of the Hops Marketing Board for allocation to commercial specialist propagators. When this nucleus is worked up, a source of the variety freed from the restrictions imposed on existing sources by the Progressive Verticillium Wilt of Hops Order will be available to growers.

Acknowledgements

The writer is indebted to Dr. P. W. Talboys who devised and supervised the *Verticillium* testing procedure, to Mr. J. T. Legg who supervised the virus testing, and to Miss C. L. Jary for assistance in roguing the material before issuing to propagators.

The writer also wishes to thank Messrs. Whitbread and Co. Ltd. for access to their farm records concerning the variety and for material from which the *Verticillium*-free stock was produced ; and Mrs. A. E. Burton, Messrs. P. Highwood Ltd., R. E. Reader, Esq., and Wm. Tipples Farms Ltd. for access to their plantings of this variety. Thanks are also due to the Propagation Committee of the Hops Marketing Board for their co-operation in distributing the *Verticillium*-free stock.

Summary

Field studies of Whitbread's Golding Variety grown under commercial conditions in different localities show the Wilt tolerance of the variety to be satisfactory and comparable with that of Keyworth's Mid-season. A stock of the variety shown by test to be free from *Verticillium* has been established and distributed to commercial propagators.

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ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1956

By A. M. MASSEE

1. Clay-coloured Weevil (*Otiorrhynchus singularis* L.)

The Clay-coloured Weevil, in both adult and larval stages, attacks the majority of top and soft fruits including peach. During the latter part of February and March, peaches growing against walls and in the open at East Malling and in the Maidstone district suffered damage from these weevils feeding on the base of the buds and causing them to shed. The weevils worked only at night and few were found resting during the day. Although the injury was more severe on peaches growing in sheltered situations it was not confined to such trees. The sheltered position of many of the bushes probably accounts for the earliness of the attack.

Severe weather in January and February often causes buds to drop off, and this type of injury may well be mistaken for that caused by the Clay-coloured Weevil. Injury of a similar nature has been seen in previous seasons, when birds were thought to be responsible for the damage.

In several plantations near Maidstone, Clay-coloured Weevils damaged basal buds of raspberries during April and May, causing ' blind ' buds on many of the canes.

2. Summer Fruit Tortricid (*Adoxophyes orana* F.R.)

The Summer Fruit Tortricid was first recorded in England in 1950, and at that time was regarded as a pest of considerable potential importance on both apple and pear. It occurred in orchards to the north of the downs, from the Medway estuary to Sandwich and, in addition, it established itself in a few orchards inland.

Since 1950 the behaviour of this tortrix has been somewhat unexpected ; it did not spread rapidly to all the fruit growing districts of Kent as had been predicted, but established a balance with other insect species of the orchard so that it caused little serious injury to fruit. The species has gradually extended its range to mid-Kent and the Weald and even to two localities in Essex and one in the Midlands. During 1955 and 1956 the Summer Fruit Tortrix has still further extended its range in Kent and it occurs much more commonly in many orchards.

The larvae mainly confine themselves to feeding on the foliage, causing negligible damage to the crop, but in 1950 much damage was caused in a few localities to early fruiting varieties such as James Grieve by the larvae feeding on the flesh of the fruits in July and August.

The widespread occurrence of this insect in Kent makes it essential for all growers to recognize the species so that control measures may be carried out should the necessity arise.

3. Apple Sawfly (*Hoplocampa testudinea* Klug)

The Apple Sawfly is much more regular in its appearance in the apple orchard than the allied species associated with plum, and it usually occurs year after year in the same orchard, although its numbers vary markedly from season to season.

Populations of Apple Sawfly were below normal in 1956, and in consequence many fruit growers wisely decided not to spray against it, but rather to utilize the species as a beneficial insect assisting in thinning out the bloom in a very heavy blossom season.

The insect usually selects white flowered varieties of Apple for oviposition, but when these are in their off year, it selects varieties with coloured flowers. The Apple Sawfly was, however, very common in a Bramley's Seedling orchard at Matfield during the third week in May. The oviposition punctures and eggs were very plentiful on this variety, but the sawfly was not present in a Cox's Orange Pippin orchard close by. Another interesting example of the sawfly occurring in the orchard of a coloured-flowered variety was observed at West Peckham at the end of May. A standard orchard of Lord Derby was infested and the grower had found it necessary to spray against the pest for the past five years.

4. Plum Sawfly (*Hoplocampa flava* L.)

The Plum Sawfly, though usually very irregular in its appearance in Kent, proved far more common near Maidstone than for several years past. It was also plentiful near East Malling, and

severe attacks were noted at Wateringbury and Plaxtol. As is usual, the attacks were mainly confined to Czar, but two other susceptible varieties, Belle de Louvain and Victoria, were not infested. Conversely, a plum orchard at Southfleet, Kent, which is very prone to sawfly attack was not infested this year, though a large proportion of last season's crop was destroyed by this insect. A damson orchard at East Malling was also infested, the most susceptible variety being Farleigh damson.

5. Dock Sawfly (*Ametastegia glabrata* Fall.)

The injury caused by fully grown larvae of the third generation of the Dock Sawfly by their tunnelling into the flesh of mature apple fruits was less common during the autumns of 1955 and 1956 than for several years. The larvae usually eat out a straight, cylindrical hole about 1 inch in depth, but a novel kind of injury was reported from Ash in which the larvae made irregular and curved tunnels in the flesh of the fruits.

Hibernation occurred on a five-year Cox's Orange Pippin plantation at East Malling, and some of these small trees supported some thirty or more Dock Sawfly larvae. In every case the larvae had tunnelled into the centre of a shoot or a spur which had been cut back during pruning the previous winter and overwintered there. A few larvae were found hibernating in scars and cracks of canker wounds which were present on many of the trees.

The orchard bore a very poor crop, and since both docks and fat hen—the host plants of the larva —were not growing in the orchard, it is likely that the mature larvae had come from an adjacent plantation of much older standard trees, where docks and fat hen grew in profusion. A few larvae were noted hibernating on the trees of the latter plantation.

6. Common Earwig (*Forficula auricularia* L.)

For many years the Common Earwig has been suspected of injuring mature apples in Kent, but it was not until some two or three years ago that earwig damage was recognized, and it is now regarded as serious.

Damage by earwigs is widespread in Kent, and large populations have been noted in grass orchards near Canterbury and in Mid Kent, where considerable injury has been caused to ripe, unpicked fruits. Reports of damage have also been received from the Weald, mainly from near Marden.

Earwig damage is more common in grass orchards than in cultivated plantations, and it usually occurs from late August to early October. The injury occurs on unpicked mature fruits and on fruit in boxes under the trees. The earwig injures fruits either by feeding on sound flesh or by enlarging small punctures made by other insects. The damage is characteristic and consists initially of a circular hole some 4–5 mm. in diameter in the cheek of the apple ; the earwig then proceeds to hollow out a shallow cavity which is usually considerably larger than the entry hole.

Some varieties appear more subject to attack than others ; Worcester Pearmain, Cox's Orange Pippin and Miller's Seedling being particularly susceptible, while Bramley's Seedling in an adjacent orchard escaped attack.

7. Apple Sucker (*Psylla mali* Schm.)

The Apple Sucker has not been regarded as an important apple pest for many years in Kent, although careful examination of an orchard usually discloses a small population of this insect. Apparently a few Apple Suckers survive irrespective of the spray programme adopted. The Apple Sucker is one of the predominant insects in unsprayed orchards, and high populations persist in badly sprayed and neglected areas. Probably the low populations of this insect found in well-cared-for orchards migrated from neglected fruit plantations.

Occasionally considerable populations of Apple Sucker build up in commercial orchards, and an interesting example occurred in a grass orchard in the West Malling district. The orchard contained Worcester Pearmain, Cox's Orange Pippin, Bramley's Seedling and Lord Derby. By the middle of May most of the petals of each flower truss were stuck together, the flowers turned brown, the trusses withered and died, and the whole crop was destroyed. Fortunately this kind of damage is not common in commercial orchards today, but it illustrates what might happen when an orchard is neglected for a number of seasons.

8. Fruit aphids

In contrast to the autumn of 1954, when the Oat-Apple Aphid was abundant in commercial orchards, this insect was scarce in the autumn of 1955, and only small infestations were noted in the majority of apple orchards in the following spring. In a few orchards in North Kent, however, heavy infestations were seen during blossoming.

Another species, the Green Apple Aphid, which occurs on apple all the year round, was prevalent

in commercial orchards and persisted throughout the summer, causing severe leaf-curl on one-year-old shoots in July. Large clusters of shiny black eggs were numerous on the young shoots in the autumn.

The Leaf-Curling Plum Aphid was also very common in plum and damson plantations near Maidstone, and considerable leaf curl was noticeable in May and June.

The eggs are laid on spurs and shoots in autumn and hatch early in the spring, frequently before the buds burst. The aphids feed at the base of the buds at first and later on leaves and blossoms.

There is a widespread belief amongst fruitgrowers that winter washes and delayed dormancy sprays do not kill the eggs of this aphid, and in consequence severe infestations build up in the spring. In fact, however, the eggs of this species are destroyed by winter washes if the application is thorough.

The migration of the aphid to its summer hosts, e.g. aster, clover, etc., may start as early as May, but as long as the trees are in a growing condition, some of the aphids remain on them.

9. Black Currant Gall Mite (*Phytoptus ribis* Nal.)

The Black Currant Gall Mite is again increasing in parts of Kent, and in some districts infestations as severe as those experienced some twenty-five years ago are by no means uncommon. This is particularly serious, since the increase in infestation is paralleled by an ever-expanding acreage, so that the risk of the mite spreading to the newly-planted fields is considerable.

A little-known species of Phytoptid mite was observed in numbers on the undersides of the leaves of the variety Baldwin at Reading in May. It proved to be the free-living species *Oxypleurites neglectus* Mass. There is no evidence that the mite causes any harm to the plant, but the mites feeding on the undersides of the leaves may produce a brown, rusty appearance of the leaf surface. This species overwinters in ' big buds ' in association with the Black Currant Gall Mite.

10. Bryobia Mite on top fruits

A severe infestation of Conference pears caused by a species of Bryobia was reported at Rainham, Kent, at the beginning of May. The leaves became much discoloured and brittle, and many were curled and misshapen. The attack persisted for several weeks and required three applications of acaricide to achieve control. The mite was noted in the plantation the previous year, but the population remained low throughout the season.

Another severe infestation was noted in a standard apple orchard of Lord Derby and Bramley's Seedling at Capel, near Tonbridge, during the second week of May. The mites were present in all stages of development on the leaves, which were brittle and turning brown. Eggs were present on the shoots and trunks of the trees, but not on the foliage. The mites were first noted in the orchard two years ago, but although they occurred throughout the summer the populations remained low.

A striking illustration of a severe Bryobia infestation was noted in a commercial orchard at Plaxtol, Kent, in July. A ten-acre plantation of standard Lord Derby trees, which have been cultivated continuously for forty-eight years, carried an enormous population of mites of all stages, including eggs. They occurred on the leaves, stems, branches and tree trunks. The majority of the eggs were deposited under loose bark on the trunks, but a considerable number were laid on the petioles of the leaves. So many cast skins of the mites were attached to the undersides of the larger shoots and main branches that they appeared whitish-grey. By the end of July all the mites had died, having reached maturity and deposited their eggs on the tree trunks. It is thought that the enormous egg population present on the trees will remain until the following spring.

The effect of the feeding of this vast population of mites on the trees was profound. All the leaves were discoloured, many turned a pale yellow colour, and defoliation was considerable. The effect upon the crop was even more striking. All the fruits were considerably undersized at the end of July and of a yellowish colour, and fruit drop was considerable. The condition of the trees improved later, and fruit size and quality were also a little better. The Bryobia Mite was also found in an adjoining plantation, but the infestation was less severe. An examination of Lord Derby and Bramley's Seedling on a neighbouring farm indicated that the Bryobia Mite was present there also, but the population was small.

A species of Bryobia Mite was found feeding on ivy near the badly attacked plantation. Specimens were collected with a view to determining their relationship to those of the orchards.

The fact that a species of Bryobia Mite occurs in ' pockets ' in commercial apple and pear plantations in various parts of Kent, and that in some instances the infestations may be very considerable, suggests that a new species or strain exists which is gradually building-up on these top fruits. The fact that the mite is extending its range in Kent on apple and pear may well be important, since it will be recalled that some thirty years ago the more familiar species, namely the Fruit Tree Red Spider Mite followed exactly the same pattern in the orchards of Kent in those days as the Bryobia Mite is doing today.

The Bryobia Mite is always present in neglected or unsprayed orchards, but the presence of the same mite in commercial orchards presents a new phenomenon which must be looked into carefully in the field.

Summary

Brief accounts are given of some interesting insects and mites observed in 1956. Some of the more important are the Summer Fruit Tortricid, Dock Sawfly, Common Earwig, Apple Sucker, Fruit Aphids and the Bryobia Mite.

A CONTRIBUTION TO THE BIOLOGY OF THE PEAR SUCKER, *PSYLLA PYRICOLA* FÖER.

By M. B. GEORGALA*

Introduction

According to Massee (1954) the pear sucker *Psylla pyricola* Föer. is generally distributed in Kent, and throughout the south-eastern counties.

This investigation took place between March 1955 and January 1956. The objects were to study the more important aspects of the biology of *P. pyricola* in south-eastern England, with a view to facilitating the correct timing of spray applications for its control.

Although several species of *Psylla* have been reported attacking pear, the winter and summer forms of the species present in these investigations were submitted to Mr. F. Laing and proved to be *P. pyricola*.

A detailed paper describing other species found on pear, together with characters for their determination has recently been published (Wille, 1950).

Methods

These investigations were conducted both in the insectary and in the field.

(a) Insectary methods

Immature and adult individuals were removed from the field population and confined in a well-ventilated bird-proof insectary, where they were reared on potted pear trees of Conference and Comtesse du Paris.

The reproductive capacity of the winter females was studied by confining them to twigs in small plastic pill boxes, from which most of the lid and bottom were removed, and the apertures covered with gauze.

Summer adults were confined to the lamina by means of the leaf cage shown in Fig. 1(*a*). It consisted of a $\frac{1}{2}$-inch length of glass tube, $\frac{3}{4}$ inch in diameter, glued over a hole of similar diameter cut in a $\frac{1}{16}$-inch perspex square. The cage was clipped to the leaf in the same way as the nymphal leaf cages (Fig. 1(*b*)). After being placed in the cage, adults were confined by a cork with a gauze covered aperture.

The development of individual nymphs was studied, using leaf cages as described by Newcomer and Yothers (1929) (Fig. 1(*b*)). The majority of the nymphs were observed to take up a half secluded position with their heads in the angle formed by the wall of the cage and the leaf surface. The exuviae were invariably cast towards the centre of the cage, and the duration of the instars could be observed with accuracy. Losses were so small that no precautions were necessary to prevent nymphs from leaving the cages.

When the nymphs reached the fifth instar they were placed in special cells in which they could complete their development without the adults escaping (Fig. 2). The cells were used as follows. A cluster of leaves at the end of a 4-6 inch length of twig was removed from a pear tree. After removal of the laminae the bunched petioles were pushed through hole (A) in the perspex plate and kept in position with plasticine, with the woody base resting in a dish (B) filled with water. After the nymphs were transferred to the petioles they were covered with a cell (C) consisting of a $\frac{1}{2}$-inch length of glass tube of $\frac{3}{4}$ inch diameter covered at one end with cloth gauze. These cells were also used to study the pre-oviposition period, egg production and longevity of the adults.

(b) Field methods

These observations were based on a population of *P. pyricola* infesting a local orchard of large bush Conference pear trees. The suckers were allowed to develop unhindered at one end of a plot of 104 trees, while the remainder of the orchard received a commercial spray programme. The unsprayed plot was divided into eight blocks each containing eight large bush trees. The seasonal history was studied by sampling the immature and adult stages on one tree per plot, a different tree being used on each occasion. When the foliage deteriorated late in the season it was not always possible to vary the trees and successive samplings were often taken from the same tree. The following sampling methods were used:

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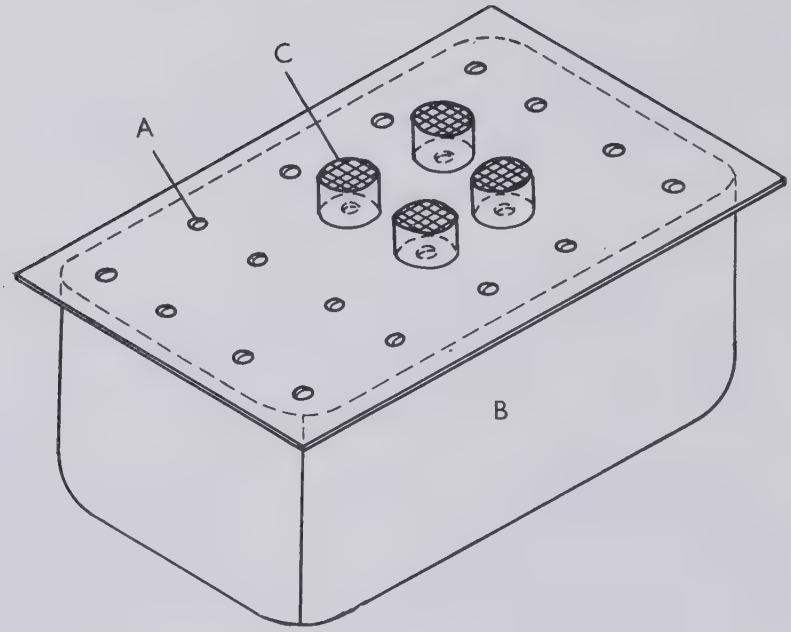

FIG. 2
Cells used for adult emergence

(i) In the spring, twenty spurs on each of eight trees were marked, and observations made on oviposition and hatching of eggs laid by winter females.
(ii) Seasonal fluctuations in immature stages were studied by means of a regular sample of ten leaf clusters from each of eight trees. Spur leaf clusters only were used during the first generation, but where first generation adults had laid eggs indiscriminately on all parts of the foliage, both spur and extension growth leaf clusters were used.
(iii) Adult fluctuations were recorded with a beating tray. The sample used was the number of adults obtained by tapping all available branches on each of eight trees. On cool dull days, the time of sampling was immaterial, but in warm summer weather the sampling was done at 9 a.m. before the adults became too active.

Insectary results

A feature of the adult activity was the high reproductive capacity of the females (Table I). The number of eggs laid was much higher than the average of 93 recorded by Wille (1950) in Switzerland.

TABLE I

DATA FOR ADULT FEMALES FOR EACH GENERATION

	Number of specimens	Longevity (days)			Preoviposition period (days)			Oviposition period (days)			Total eggs		
		Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
1954-55 winter adults ..	7	—	—	—	—	—	—	31·3	63	16	216·4	477	129
1st generation adults summer, 1955 ..	13	25·0	38	20	9·2	14	5	15·8	28	10	192·7*	459	51
2nd generation adults summer, 1955 ..	7	73·6	110	52	7·4	10	3	59·9	75	49	143·1	239	41

* Based on 21 specimens.

The reduced oviposition by second generation females was probably due to specific conditions prevailing in the insectary. In several females it was noticed that the ovipositor became clogged and encrusted with honeydew on which there was some fungus growth. Although still gravid, the females failed to lay when in this condition.

In the insectary the average longevity obtained for first generation females was 25 days, whereas in the second generation females had an average life span of 73 days. This was also consistent with field observations.

Mating appeared to be of frequent occurrence. Twenty-seven matings by winter adults in the spring of 1955 showed an average duration of 5·6 minutes with a maximum of 18 minutes and a minimum of 2 minutes.

In spring the average incubation period in the orchard was 22 days at a mean temperature of 49° F. (Table II). This agrees closely with the interval between oviposition and hatching recorded in the field (Fig. 3). The incubation period for eggs of the two summer generations was determined

TABLE II

LENGTH OF INCUBATION PERIOD IN DAYS, FOR EACH GENERATION

	No. of eggs	Average	Maximum	Minimum	Average temp. (°F.)
1st generation	31*	22·0	26	14	49
2nd generation	40†	10·5	13	8	62
3rd generation	69†	8·0	8	8	66

* Using marked eggs in field.
† In insectary.

in the insectary. For the second generation the period averaged 10·5 days at a mean temperature of 62° F., and for the third generation 8 days at 66° F.

TABLE III

DURATION OF NYMPHAL INSTARS IN DAYS FOR EACH GENERATION

	No. of specimens	Average duration of instars in days					Av. length of nymphal period	Max. length	Min. length	Average temp. (°F.)
		1st	2nd	3rd	4th	5th				
1st generation	*	4·4	4·8	5·2	6·4	10·1	30·9	—	27 (one specimen)	50
2nd generation ..	22†	2·9	3·2	3·1	4·3	9·1	22·6	29	15	63
3rd generation ..	16†	4·4	3·1	4·0	5·9	11·4	28·8	33	23	57

* The average length of the instars for the first generation was compiled from individuals that did not complete their development, or which were studied only in the final instars.
† Males and females not separated because of variation in rates of development in both sexes.

Developmental data for nymphs is presented in Table III. There were five instars and their development was rapid in the first three instars but slower in the fourth and especially in the fifth. The average development for all instars combined was 30·9 days at an average temperature of 50° F. for the first generation, and 22·6 days at 63° F. and 28·8 days at 57° F. for the second and third generations respectively.

Field results

Generations

Three generations of *P. pyricola* were recorded in the field during 1955. Despite the overlapping of generations which began to occur in mid-June, the subsequent population peaks for both adults and nymphs could be easily discerned.

During the latter half of March, 1055, the dark-coloured winter adults which had emerged the previous autumn mated and began to lay. The eggs were mainly laid in the cracks and crevices of the bark immediately below spur buds, or on the underside of 2–3-year-old wood which was slightly rough. Some eggs were also laid on very young foliage. The rate of oviposition and hatching of these eggs is shown in Fig. 3. Each point on the graph represents the total number of eggs on 100

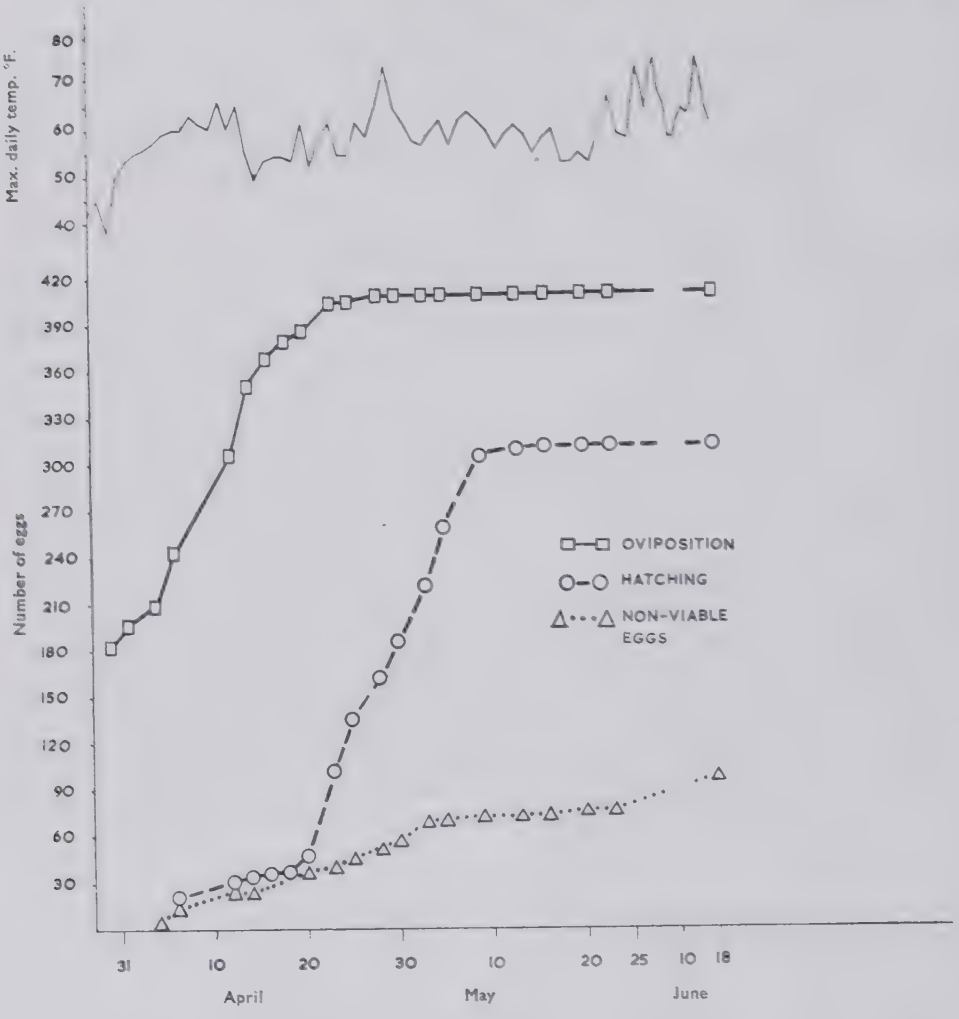

FIG. 3

Oviposition and hatching of spring eggs

marked spurs. The last observation was made on 18th June to determine the number of non-viable eggs remaining. In this figure the time scale is halved and graph lines broken at the end of May, to allow the final reading to be shown.

Hatching of spring eggs started at bud burst on 6th April, reached a peak between 20th April and the end of the month, and was complete by full blossom on 7th May. Isolated winter adults were recorded until the first week in June, by which time the light-coloured summer adults of the first generation were approaching their peak emergence period (Fig. 4). Each point on the graph represents total adults per sample of eight trees, and eggs and nymphs are represented by the total number obtained from ten leaf clusters from each of eight trees.

There was comparatively little spread of first generation adults into the rest of the orchard, and the population decline that followed must be largely attributed to natural mortality. However, by the time that peak emergence of the second generation adults occurred at the end of July and beginning of August, the foliage was in such poor condition as a result of sucker, mite and scab attack,

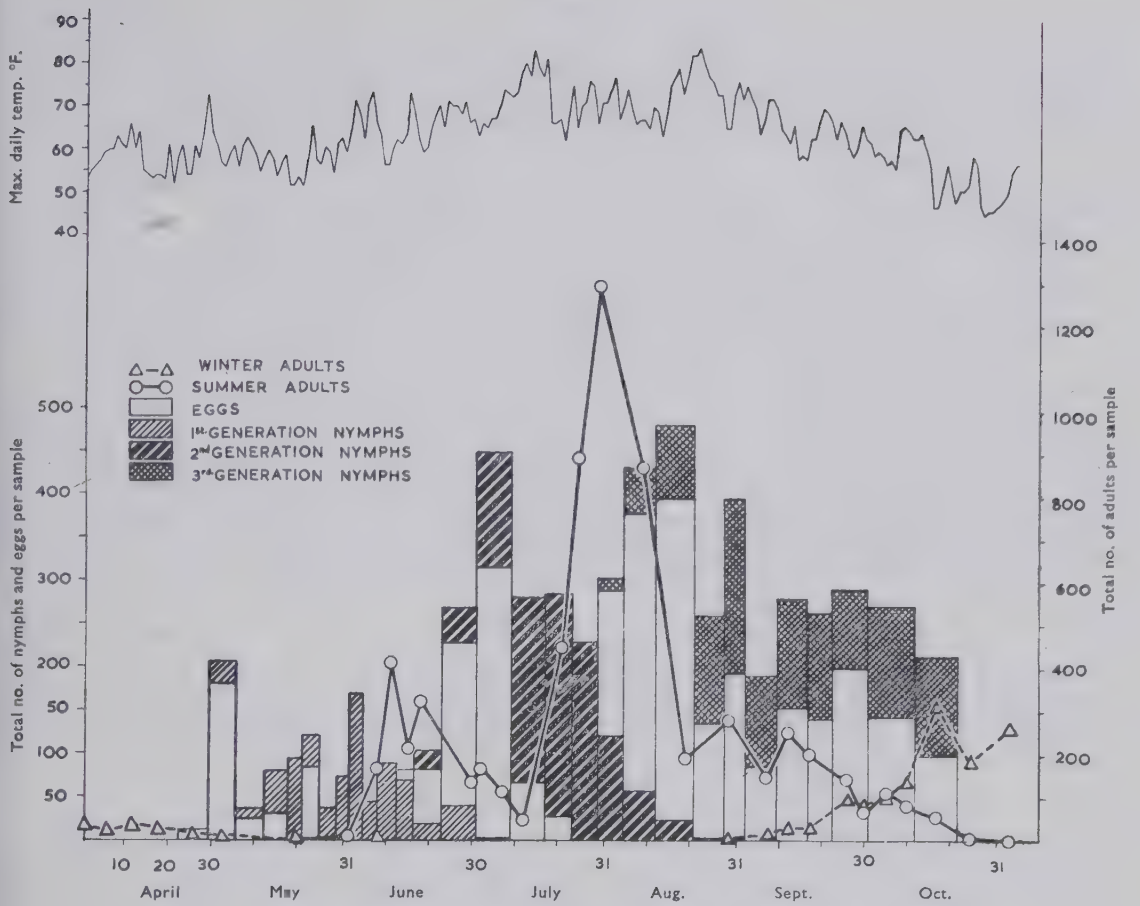

FIG. 4

Seasonal cycle of *Psylla pyricola*

that the majority of the adults migrated out of the plot. Second generation eggs were recorded on the foliage until 18th October, after which the lack of foliage made sampling impracticable. Eggs could be found on the foliage outside the plot until 26th October, when the foliage here also became useless for further sampling.

The third generation produced dark-coloured over-wintering forms, which were first recorded at the end of August. Most of the third generation developed outside the plot where the foliage was better. The rate of development within the plot and outside was quite comparable, though population levels differed. On 17th October, during peak emergence the average number of winter adults per tree on eight trees in the plot was 39 compared with 400 per tree on twelve trees outside the plot.

Distribution of eggs and nymphs on foliage

Summer generation females laid their eggs on the foliage. The dorsal surface of the leaf was preferred for oviposition, and in the population census only eggs on dorsal surfaces were recorded. This contrasts with the findings of Lal (1934) in Scotland, who observed that the summer females of *P. pyricola* laid mostly in grooves of leaf petioles and rarely on leaves. In a population sample on the 4th July, the 315 eggs recorded were distributed as follows:

On petioles	33
Under leaf	6
Dorsal margin	67
Dorsally, in vicinity of midrib ..	209

On each sampling date the distribution of the five nymphal instars on the foliage was noted (Table IV).

TABLE IV

DISTRIBUTION OF SECOND GENERATION NYMPHS RECORDED BETWEEN 8TH AND 26TH JUNE

Instar	Number on lamina	Number on petioles	% under leaf
I	304	0	90·1
II	236	1	74·6
III	219	6	77·1
IV	96	10	85·4
V	204	32	58·3
	1,059	49	

Nymphs, except for those of the fifth instar, had a decided preference for the underside of the leaf. Only 4·4 per cent of the nymphs were recorded on the petioles, and here the favourite site was between the bases of the petioles. In the first generation more nymphs (17·1 per cent) were found on petioles. After defoliation had occurred many fifth instar nymphs were found feeding on the current season's wood in the immediate vicinity of a bud. They were recorded in these positions in decreasing numbers until 12th December, 1955. From the numbers of newly-emerged adults observed during late November and early December, it would seem that these nymphs matured safely.

Sex ratio

TABLE V

SEASONAL VARIATION IN SEX RATIO

Date	Generation	Males	Females	Ratio
14.3.55	Winter	109	82	1·33 : 1
27.7.55	Summer	108	176	0·61 : 1
10.10.55	Winter	27	42	0·64 : 1
28.10.55	Winter	110	119	0·92 : 1
23.11.55	Winter	54	56	0·96 : 1
19.12.55	Winter	73	62	1·18 : 1
3.1.56	Winter	123	97	1·27 : 1

Up till the beginning of January, 1956, when the observations were concluded, the new winter adults showed no great tendency to copulate when brought indoors. This was in marked contrast to the ready mating of adults under warm conditions in spring 1955.

From the middle of December, the ovaries of the winter females began to enlarge and turn from white to yellow. By the beginning of January, 1956, 19 out of 20 females dissected had ovary development well under way.

Hibernation of winter adults

An attempt was made to determine where the majority of the winter adults hibernated. By means of the beating tray, extensive samples were taken in apple and cherry orchards surrounding the heavily infested pears. It was concluded that the majority of the adults were hibernating on the pear trees. The spread from the pears to surrounding apples, cherries, ivy, and hedgerows was in the nature of a diffusion process of the concentrated, mobile population on the pears. The greater the distance from infested pears the fewer the adults that could be found in any given site.

On the pear trees the adults were seldom found in bark cracks on the trunk and main branches. They favoured sheltering among the cracks and crevices of spur growth, while some adults chose to rest near the large terminal buds of one-year-old shoots. On the 19th December, detailed counts of ten branches of similar size showed a total of seven adults among the terminal buds of one-year-old shoots, while 96 were sheltering on the spurs. After the heavy frosts of December, 1955, adults covered with ice crystals were readily found in exposed positions on spurs and shoots. On apples near the pears most adults were also found on branches with spur growth. Virtually no winter adults were found under the peeling bark of apple trees. Very small numbers were collected from ivy and hedgerows despite the fact that heavily infested pears were only a few feet away.

Natural enemies

The predacious Anthocorid bug, *Anthocoris nemorum* L. fed readily on eggs and nymphs. The following Hymenopterous species were reared from mummies of fifth instar nymphs of the first generation: *Trechnites psyllae* Ruschka, *Psyllaephagus* sp. and *Lygocerus* sp. No parasitization was noticed in the later generations.

Damage

Until the emergence of the first generation adults the infestation was patchy. By the end of the second generation the foliage was in very poor condition, but it had also suffered as a result of attack by the mite *Metatetranychus ulmi* (Koch) and Pear Scab *Venturia pirina* Aderh.

Although the nymphs produced abundant honeydew from the second week in July up to the first fortnight in August, the Sooty Mould fungus *Cladosporium herbarum* Fr. (Link ex Fr.) was not serious, although defoliation of the trees was rapid during the second half of September and October.

Discussion

A feature of these observations was the very large population of *P. pyricola* that had built up by the end of the summer from the small, scattered number of adults which survived the winter of 1954-55. The major impetus came with the emergence of the first generation adults, which left an even distribution of eggs on the trees. In 1955 there occurred a period of approximately two weeks at the end of May and beginning of June when only nymphs and young adults were present. This would have been the best time to apply control measures during 1955.

Acknowledgements

The writer is indebted to Mr. H. W. Edmonds, Fant Farm, Maidstone, for allowing these investigations to be made in his orchard. The determination of the Pear Psylla was made by Mr. F. Laing, formerly of the British Museum (Natural History). Messrs. R. D. Eady and G. J. Nixon of the British Museum identified the parasites.

Summary

Techniques for the detailed study of the Pear Sucker, *Psylla pyricola* Föer., are described, and laboratory data on the rearing of adults, eggs and five nymphal instars are given. Field observations showed that three generations occurred during 1955 in south-eastern England. Despite overlapping of summer generations the population peaks could be easily discerned.

The two summer generations produced light-coloured adults in June and July-August respectively. The third generation produced dark overwintering forms in October. The overwintering forms hibernated mostly on pear trees, mainly among the spur growth.

Large amounts of honeydew were present in July and August, but the fungus *Cladosporium herbarum* Fr. (Link ex. Fr.) did not develop to any great extent in 1955.

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SOME EXPERIMENTS ON CONTROL OF GROUND BEETLE DAMAGE TO STRAWBERRY

By J. B. BRIGGS

Introduction

Ormerod (1895) and Warburton (1895) first noted Ground Beetle damage to strawberry fruits in England. Walton and Kearns (1931) and Hodson and Gleed (1938) reported on further outbreaks and suggested measures for cultural control. Damage has been observed at East Malling since 1952, when limited research on this problem was started. Recent enquiries indicated that damage was rather widespread, and for the past two seasons research has been intensified. Although recommendations for chemical control cannot yet be made, information of value to growers and advisers has been obtained and is summarized in this paper.

Description of damage and species responsible

Two distinct types of damage (Fig. 1) to strawberry fruits are caused by Ground Beetles. The first type, primarily caused by *Harpalus rufipes* (Deg.) the Strawberry Seed Beetle, and probably contributed to, at least at East Malling, by *H. aeneus* (Fab.), consists of the removal from the fruit of the seeds, which are then split open ; the kernels are eaten and the husks discarded. A seedless macerated area accompanied by the discarded husks typifies this damage. The other type of damage, primarily caused by *Feronia melanaria* (Ill.) and *F. madida* (Fab.), consists of large holes made in the flesh of the fruit. This may be distinguished from bird or slug damage by the holes being on the side of the fruit nearest the ground (whereas birds peck the top) and by the absence of scummy macerated tissue left by slugs. Other species of beetles named by earlier authors including *Abax parallelopipedus* (Pill. and Mitt.), *Calathus fuscipes* (Goeze) and *Nebria brevicollis* (Fab.) are never abundant enough at East Malling to contribute materially to the damage ; the latter did not feed on fruits offered in the laboratory.

Biological notes

These beetles, and some others with which the adults may be confused, are illustrated in Fig. 2. A full report of observations on their biology will appear elsewhere ; the following notes summarize their life cycles and habits.

Harpalus rufipes.—The milky white, translucent eggs, nearly 3 mm. long, laid singly or in groups of two or three from mid-July until late September in well-compacted weedy soil, hatch in two or three weeks. The larva, off-white in colour with brown head, thorax and appendages, is common in small strawberry beds during autumn when it is found on the surface of the soil at night. During the winter it has only been found at depths of from 2 to 18 inches on the fringes of strawberry beds, where larvae, and later pupae and newly-emerged beetles remain until late July when a new generation appears at the soil surface. Of a variety of items of animal and vegetable origin offered as food in the laboratory, the young larvae have only consumed the seeds of various weeds, of which Fat Hen (*Chenopodium album*) seems to be preferred. It is significant that the larvae and later immature stages found were under soil on which there had been a heavy fall of seed of this species the previous autumn, which, washed or drawn down worm holes, probably provided food. The newly-emerged beetles are white and do not assume the completely black colour of the mature beetles for several weeks, or even until the following spring, if their emergence is late in autumn. They do not reproduce in the year of emergence, laying their first eggs (some fifty are laid by each female) in the following summer, and continuing for one and perhaps more seasons thereafter. The mature beetle is black, 10–15 mm. long, with golden pubescence on the wing cases, and brown legs. Overwintering adults have been found very abundantly in soil close to strawberry beds at a depth of 4–8 inches, under old Fescue grass cut infrequently, so that a mat of roots and laid grass gave insulation to the soil below. Numbers decreased under couch grass in a headland, with increasing distance from the end of the bed. The beetles, active at night from April to late November, are more common where there is some shelter from hot dry conditions. By retrapping marked beetles, a movement of 35 yards in 5 nights has been recorded. After hibernation, movement is probably at random until a supply of food is met with, when numbers increase in the strawberry bed immediately before and during picking. The infrequency of light trap captures suggests that flight into the beds may not be of great importance.

H. aeneus.—The life history of this species is broadly similar to that of *H. rufipes*, as are the

immature stages, except that they are smaller. The adult beetles, 8–10 mm. in length, have brown legs and iridescent green, blue, or red wing cases. Though never as numerous as *H. rufipes*, this species may contribute to fruit damage.

Feronia melanaria.—The eggs of this species are laid in August and September in the soil. The larva, with dark brown head, thorax and appendages, grows to about an inch in length. It has been trapped in strawberry beds from August until April. In the laboratory larvae feed readily on the larvae of a Vinegar Fly (*Drosophila* sp.). In late May a few pupae were found at a depth of a few inches beneath a strawberry plant. Beetles emerged in the laboratory from these in early June, at which time a large increase in the numbers trapped per day in strawberry beds always occurs, doubtless due to supplementation of a sparse overwintered population by new emergences. Beetles remain abundant in strawberry beds until late September.

Feronia madida.—The immature stages of this species are similar to those of *F. melanaria*, but the hard parts of the larva are a lighter brown. Mature larvae and pupae are found in gardens, woods, and the edges of fields, and fewer adults are found in strawberry beds than *F. melanaria*, being probably immigrants from a breeding site at some distance. The adults may be distinguished by the shape of the wing-cases, more shining than in *F. melanaria* ; the legs are sometimes chestnut brown.

Control

Cultural recommendations

The proximity of grassed headlands and landways, rickyards, box stacks, woods and other situations where beetles may overwinter should be avoided as far as practicable when planting strawberries, and if the bed is already established, such features should, where possible, be removed. It is probably insufficient to burn off or spray headlands with weedkillers as the insulating property of the surface organic matter is largely unaffected by such treatment. Frequent cultivation of the alleys *and the surrounding area* before and after cropping deprives the adults of shelter and food. Straw should be placed in position as late as possible and removed as soon as possible, whatever method of disposal is employed.

Experiments in chemical control

General experience and laboratory trials showed that DDT failed to reduce the damage. Of a number of commercially available insecticides tested in the laboratory, dieldrin and aldrin showed most promise. Because of the mobility of these beetles, large areas would be necessary for field trials to give conclusive results. Small-scale trials to produce information on timing, phytotoxicity and residue were undertaken with dieldrin, selected because it was suitable for use as a wet spray which might be combined with applications made against other pests and diseases.

In the first trial, two plots each of twenty-four plants of Auchincruive Climax were sprayed on 20th June, 1955, with 0·2 per cent dieldrin emulsifiable liquid, four days before picking started, the leaves, fruit, and straw being thoroughly wetted. Two more plots, similarly sprayed, were surrounded with a barrier made of asbestos sheet sloped slightly outwards, buried 4 inches in the soil, and topped with greasebanding compound. Two further plots were left untreated. Four traps were set in each plot, and these were separated from each other by at least 10 yards of cultivated soil. All fruits were picked and graded from 24th June until 6th July, thereafter samples were taken. Results (Table I) show that spraying reduced both forms of damage markedly, as well as the number of *Feronia* sp. trapped. The figures for *Harpalus rufipes* trapped during the picking period are not proportionate to the decrease in fruit damage ; the difference that emerges after 6th July suggests that during the earlier period the figure for numbers trapped on the untreated plots is depressed by inactivity of the beetles in the presence of ample food. The continued reduction of all species until 16th August was not necessarily due to persistence of the insecticide, but may reflect an earlier depletion of the population. However, fewer beetles were trapped on the plots with a barrier, showing that reinfestation of the other plots did take place.

Fruits from the sprayed plots and other fruits from plots of Royal Sovereign sprayed in 1956 with 0·1 per cent dieldrin emulsifiable liquid at various intervals before picking, were subjected to chemical analysis in the Plant Protective Chemistry Section ; results, to be fully reported elsewhere, indicated dieldrin residues of the order of 6–8 parts per million on fruits picked immediately after spraying, declining to 0·5–1 p.p.m. on fruits picked 27–35 days after spraying. In laboratory tests, 12–57 beetles of *H. rufipes* and *F. melanaria* were offered similar fruits. Forty-eight hours after exposure to fruits sprayed 0–8 days previously, all beetles were dead or fatally paralysed. Fruits sprayed 9–22 days previously gave variable results, and those sprayed 27–35 days before gave no mortality. The residue considered tolerable on strawberries by the Food and Drug Administration

TABLE I

PERCENTAGE OF DAMAGED FRUIT AND NUMBERS OF TRAPPED BEETLES, AUCHINCRUIVE CLIMAX, 1955

Date	Treatment								
	0·2 per cent dieldrin and barrier			0·2 per cent dieldrin			Untreated		
	Percentage of damaged fruit								
	Total fruits	*Harpalus* damage	*Feronia* damage	Total fruits	*Harpalus* damage	*Feronia* damage	Total fruits	*Harpalus* damage	*Feronia* damage
24th June to 6th July ..	874	0·6	0·3	968	0·3	0·9	839	22·2	11·3
13th and 18th July (sample) ..				930	0·9	1·0	941	6·4	4·3
	Number of beetles trapped								
	H. rufipes	*F. melanaria*	*F. madida*	*H. rufipes*	*F. melanaria*	*F. madida*	*H. rufipes*	*F. melanaria*	*F. madida*
21st June to 6th July ..	10	26	11	21	94	56	20	216	134
6th July to 10th August ..	19	18	17	54	44	33	189	187	297

of the United States Department of Agriculture is 0·1 p.p.m. (Martin, 1955), a standard which it is anticipated will shortly be adopted in this country. Any spray of this sort applied after the blossom opens is thus likely to give rise to residues on picked fruit considered harmful to the consumer.

An alternative use of dieldrin, suggested by the beneficial effect of the barrier in the 1955 trial, was investigated in 1956. A trench about 10 to 12 inches deep was ploughed around six strawberry plots at East Malling, and made good by spadework ; a little straw was placed in the bottom and this and the vertical wall of the trench, which adjoined the bed, was sprayed on 9th May, 24th May, and 13th June with 0·1 per cent dieldrin emulsion. If the treatment were effective, a simpler form of barrier could then be tested. Six other plots were left untreated. Results were assessed by grading fifty or more fruits from two to five sampling positions on each plot. This was done at each picking from 18th June to 2nd July ; few fruits were damaged by *Feronia* sp. and only *Harpalus* damage was recorded. The percentage of all fruit damaged in 74 samples from treated plots was 10·8, in 73 samples from untreated plots, 23·0. ' However, as variability was high it was not clear whether the apparent reduction was due to treatment.

Time has not been available for work with aldrin. Moreton (1955) suggested the use of 1½ to 2 cwt. per acre of a 1¼ per cent aldrin dust between the rows immediately before strawing ; Staniland (private communication) informed the author that by dusting the soil around the plants and in the alleys just before strawing, ' Growers (who) had been having severe losses for several years . . . had only a matter of a few fruits affected over about an acre '. However, there seems reason to suppose that this sort of treatment would lead to a residue problem similar to that where dieldrin is concerned, and in this case, too, it would seem to be wise to apply such treatments before the blossom is open.

Future work on control will include efforts to assess the value of dieldrin sprays and aldrin dust applied in the beds before the blossom is open, and, if possible, the effect of spraying or dusting over-wintering sites nearby immediately before emergence of the beetles.

Acknowledgements

The author wishes to thank Mr. R. P. Tew and Mr. L. N. Staniland for permission to refer to unpublished results and observations.

Summary

A brief account is given of the life history and some features of the biology of Ground Beetles damaging the ripe and ripening fruits of strawberry. The most important species concerned at East Malling are *Harpalus rufipes* (Deg.) and *Feronia melanaria* (Ill.). Two distinct types of damage,

Fig. 1

Damage to strawberry fruits by Ground Beetles.
Left, by *Feronia melanaria*; centre and right, by *Harpalus rufipes*

Fig. 2

Adult Ground Beetles common in strawberry fields.

At left, *Carabus violaceus*. At right, *Feronia melanaria*. Remainder, top row, left to right: *Abax parallelopipedus*, *Harpalus rufipes*, *Feronia madida*; bottom row, left to right: *Agonum dorsale*, *Harpalus aeneus*, *Calathus fuscipes*

[face page 144

caused by these and other species, are described. The adults are very active, and may invade the strawberry bed only shortly before the crop is ripe. Suggestions for cultural methods of control are outlined. An experiment is described in which a 0·2 per cent dieldrin emulsifiable liquid successfully controlled the damage, but this and other work showed that an undesirably high residue of dieldrin was present on the picked fruit, when applied at the time and in the manner described.

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PLANT PROTECTIVE CHEMISTRY

GLASS-SLIDE SPORE-GERMINATION TESTS WITH SOME OXIDATION PRODUCTS OF NABAM

By A. H. M. KIRBY and E. L. FRICK

Although the heavy metal salts of ethylene bisdithiocarbamic acid, such as maneb and zineb, are in general much superior as fungicides to the sodium salt, nabam, the latter has a much greater value than would be expected from its considerable water solubility. This is because, like lime-sulphur, it becomes much less water-soluble upon drying in a film. Although this phenomenon was early recognized (Barratt and Horsfall, 1947), no explanation was forthcoming until 1953 when Ludwig and Thorn reported that aeration of dilute (0·1 per cent) solutions of nabam for several days caused chemical changes leading to the precipitation of a yellow, amorphous material of considerable fungitoxicity ; this precipitate, given the code number G.D.26, consisted mainly of polyethylene thiuram monosulphide, with about 20 per cent of the monomer, ETM, and varying amounts of elemental sulphur. The ED_{50} against *Sclerotinia fructicola* spores was found to be 8–10 p.p.m. for the polymer and 1·5 p.p.m. for ETM (Thorn and Ludwig, 1954). A commercial product based on G.D.26 has been offered for experimental purposes in Canada (" Thioneb ") and showed some promise for control of Apple Scab and Peach Brown Rot (Ludwig, private communication).

It seemed worth while to investigate the possibility that a process might be developed in Britain giving a satisfactory product of value in fruit plantations. A series of materials obtained from a commercial source were therefore tested by the glass-slide spore-germination technique (Kirby and Frick, 1953), using spores of *Venturia inaequalis* (Cke.) Wint. and *Botrytis cinerea* Pers. *ex* Fr. (Frick, 1955).

Materials

Two series of materials, I and II, were supplied to us in 1955, and the following information has been provided regarding the preparation and properties of these materials :

Series I.—1. Prolonged aeration of 0·1 per cent crude nabam solution in tap-water (hard) gave the following :

(*a*) A light-coloured precipitate containing 70 per cent sulphur and no nitrogen, deposited during the first 24 hours ; analysis by Mr. R. P. Tew showed that the balance consisted of calcium carbonate.

(*b*) A crystalline, deep-yellow precipitate with m.p. 153–156° C. (decomp.), insoluble in water, alcohol, acetone, chloroform and carbon disulphide, and containing N = 15·4 per cent and S = 50·85 per cent.

(*c*) Extraction of the final filtrate with chloroform gave a yellow solid, m.p. 119–122° C. (without decomp.) with N = 15·4 per cent and S = 52·2 per cent ; very sparingly soluble in ethanol, soluble to the extent of 1 per cent in cold acetone, and fairly readily soluble in carbon disulphide with the almost immediate deposition of an orange-red addition compound from which the monomer could be recovered by driving off the CS_2 at 100° C.

2. Evaporation of a dilute (approx. 1 per cent) nabam solution in shallow trays, and extraction of the residue with water and chloroform, left small yields of a greenish-yellow, amorphous solid which did not melt, but shrank and blackened above 180° C. Analysis : batch (a) —N = 12·3 per cent, S = 27·2 per cent ; batch (b)—N = 11·5 per cent, S = 26·8 per cent.

3. Attempts to prepare ethylene thiuram monosulphide by oxidizing a nabam solution with acetic-hydrogen peroxide mixture in the presence of sodium cyanide gave 85 per cent yields of a product melting at 98–99·5° C. (decomp.) ; analysis : N = 15·3 per cent, S = 53·1 per cent (calculated for $C_4H_6N_2S_3$: N = 15·7 per cent, S = 53·9 per cent). This product evolved H_2S when heated alone to 80° C., or when boiled in aqueous or alcoholic suspension. It is insoluble in water, alcohol, ether, benzene, carbon disulphide or chloroform ; it dissolves with decomposition in acetone, pyridine, dimethylformamide and aqueous alkalies. It thus differs considerably from 1(*b*) or 1(*c*) which have very similar nitrogen and sulphur contents.

4. A similar oxidation procedure, without cyanide, was used to prepare ethylene thiuram

disulphide. This proved to have similar solubilities to the product I 3, and to be unstable to heat. It melted at 191–193° C. (decomp.) and its analysis agreed fairly closely with theory : N = 13·04 per cent, S = 58·7 per cent (calculated for $C_4H_6N_2S_4$: N = 13·3 per cent, S = 60·9 per cent).

Series II. –These were all obtained by oxygenation of dilute nabam solutions ; 1 and 4 from pure nabam, in accordance with Ludwig and Thorn's description, and 2 and 3 from crude nabam by an accelerated process :

1. The mother-liquor, obtained after oxidation was complete, was extracted with chloroform ; this extract yielded a solid corresponding to I 1(*c*).

2. This was the precipitate produced by the accelerated process and contained 75–80 per cent of chloroform-soluble, fungicidally active material, believed to be the monomer, the remainder being substantially sulphur.

3. This was sample II 2 freed from the bulk of the sulphur ; m.p. 122–124° C. and N = 15·8 per cent in good agreement with Thorn and Ludwig's figures for the monomer, ETM.

4. The precipitate from the process which provided II 1 was extracted with chloroform. This extract, according to Ludwig and Thorn, should have contained the monomer, and the solid left after removal of solvent had m.p. 123–124·5° C., indicating it to be the monomer.

Results

Tests with *Venturia inaequalis* were made on two occasions, samples I 1(*c*) and I 3 being included in both ; the results are summarized in Table I. Results from tests with *Botrytis cinerea*

TABLE I

Venturia inaequalis (CKE.) WINT. : INHIBITION OF SPORE GERMINATION BY NABAM OXIDATION PRODUCTS

Date of test	Sample No.	Nature of sample	Percentage inhibition at percentage concentration			
			0·01	0·001	0·0005	0·0001
7.ix.55	I 1(a)	Initial ppt. from atmospheric oxidation { Sulphur 70% / $CaCO_3$ 30% }	75·7	17·9		5·1
	I 1(b)	Chloroform insoluble ppt. from atmospheric oxidation	100	100		15·4
	I 1(c)	Chloroform extract from supernatant liquor from atmospheric oxidation	100	100		21·6
	I 2	Insoluble residue from evaporation in shallow trays	100	97·6		16·5
	I 3	Synthetic product, m.p. 98–99·5° C., expected to be ethylene thiuram monosulphide	100	100		4·2
	I 4	Ethylene thiuram disulphide, m.p. 191–3° C. ; synthesized by normal route	100	66·2		9·9
	—	Captan		95·6		
14.ix.55	I 1(c)	See above			100	1·4
	I 3	See above			100	0·0
	II 1	Oxygenation product corresponding to I 1(c)		100	100	5·8
	II 2	Crude product from accelerated process ; 75–80% active ingredient (monomer)		100	0·0	0·0
	II 3	Residue from II 2 after removal of bulk of sulphur		100	100	0·0
	II 4	Chloroform extract of crude oxygenation product		100	100	2·8
	—	Captan		100		

are given in Table II ; these tests included I 1(*c*) on three occasions and I 3 on all four. The well-known organic fungicide, captan, was included on most occasions as a reference substance.

TABLE II

Botrytis cinerea PERS. *ex* FR. : INHIBITION OF SPORE GERMINATION BY NABAM OXIDATION PRODUCTS

Sample No.*	Percentage concentration	1.iv.55			7.iv.55			21.ix.55			28.ix.55		
		Percentage spores			Percentage spores			Percentage spores			Percentage spores		
		UN	IN	G	UN	IN	G	UN	IN	G	UN	IN	G
I 1(a)	0·01				2·5	9·8	87·7						
	0·001				—	—	100						
	0·0001				—	—	100						
I 1(b)	0·01	100	—	—									
	0·001	—	—	100									
	0·0001	—	—	100									
I 1(c)	0·01	100	—	—									
	0·001	100	—	—				5·8	4·4	89·8	44·5	11·3	44·2
	0·0005							—	—	100	5·0	8·3	86·7
	0·0001	—	—	100									
I 2	0·01	62·7	19·0	18·3									
	0·001	—	—	100									
	0·0001	—	—	100									
I 3	0·01	100	—	—	6·2	48·3	45·5						
	0·001	1·5	35·8	62·7	1·3	17·8	80·8	13·6	7·2	79·2	2·0	6·2	91·8
	0·0005							—	—	100	—	—	100
	0·0001	—	—	100	—	—	100						
I 4	0·01				68·0	12·0	20·0						
	0·001				—	—	100						
	0·0001				—	—	100						
II 1	0·001							9·8	8·0	82·2	15·0	11·8	73·2
	0·0005							—	—	100	—	—	100
	0·0001							—	—	100	—	—	100
II 2	0·001							9·7	7·8	82·5	2·5	9·5	88·0
	0·0005							—	—	100	—	—	100
	0·0001							—	—	100	—	—	100
II 3	0·001							26·8	6·5	66·7	7·7	15·3	77·0
	0·0005							—	—	100	—	—	100
	0·0001							—	—	100	—	—	100
II 4	0·001							52·7	6·3	41·0	21·5	16·8	61·7
	0·0005							15·5	6·7	77·8	6·3	8·3	85·3
	0·0001							—	—	100	—	—	100
Captan	0·001							67·8	5·4	26·8	93·0	5·2	1·8

* For nature of samples see Table I and text.
UN=ungerminated ; IN=partial germination (inhibited) ; G=full germination.

As is common experience with other toxicants, *V. inaequalis* was more susceptible than *B. cinerea* to all the materials tested.

Discussion

Apart from sample I 1(*a*), which was virtually a 70 per cent sulphur preparation, all the products tested showed considerable toxicity towards *V. inaequalis* at 10 p.p.m. Moreover, samples I 1(*c*), I 3, II 1, II 3, and II 4 were highly toxic at 5 p.p.m., although no material had a high performance at 1 p.p.m. All samples save I 1(*a*) and I 4 can be said to be at least the equal of captan at 10 p.p.m. against this organism. A feature of this series is the absence of toxicity of II 2 at

5 p.p.m. compared with II 3 ; it presumably reflects the presence of some 20–30 per cent sulphur in II 2.

In the tests against *B. cinerea*, no material compared favourably with captan at 10 p.p.m. In general, toxicity to this organism was low except at 100 p.p.m. The consistency of the four results with I 3 at 10 p.p.m. contrasts with the two results at 100 p.p.m., but, with all compounds, reduction of concentration, even from 10 to 5 p.p.m., has brought about a reduction of toxicity, and the results may be said to be reasonably consistent.

The results with both organisms would agree with the view that samples I 1(*c*), II 1, II 3, and II 4 are chemically similar to each other as well as to Ludwig and Thorn's monomer, II 4 being the purest sample. I 3, however, although prepared by a process expected to give the monomer and having an elementary analysis closely similar, had both a melting-point and solubility characteristics quite different ; nevertheless, it had similar toxicity towards these two organisms.

The product differing most from those of the Canadian workers was that obtained by partial evaporation of a 1 per cent nabam solution in shallow trays, sample I 2 ; the Canadian workers used 0·1 per cent solutions for this, as well as for the aeration process (Ludwig, Thorn and Miller, 1954). As I 2 was prepared from a tap-water solution, it will have contained a little calcium carbonate, perhaps contributing to the unsatisfactory m.p. and the low figures for nitrogen and sulphur, but this does not account for the N : S ratio of near unity ; nevertheless, the biological activity of this product was just as high as those of the most active samples against *V. inaequalis*, though rather lower against *B. cinerea*.

The term nabam is a recommended common name for disodium ethylene-1:2-bisdithiocarbamate, and therefore refers to the pure, anhydrous compound only. Cox, Sisler and Spurr (1951) refer to the active ingredient of the crude, liquid preparation available in America, as the hexahydrate. This water of crystallization appears to be retained even when nabam is recrystallized from alcohol, and it increases the molecular weight by about 42 per cent ; there is no evidence that any authors, other than Cox *et al.*, have been aware of this, and hence a doubt must exist about the concentrations they have employed.

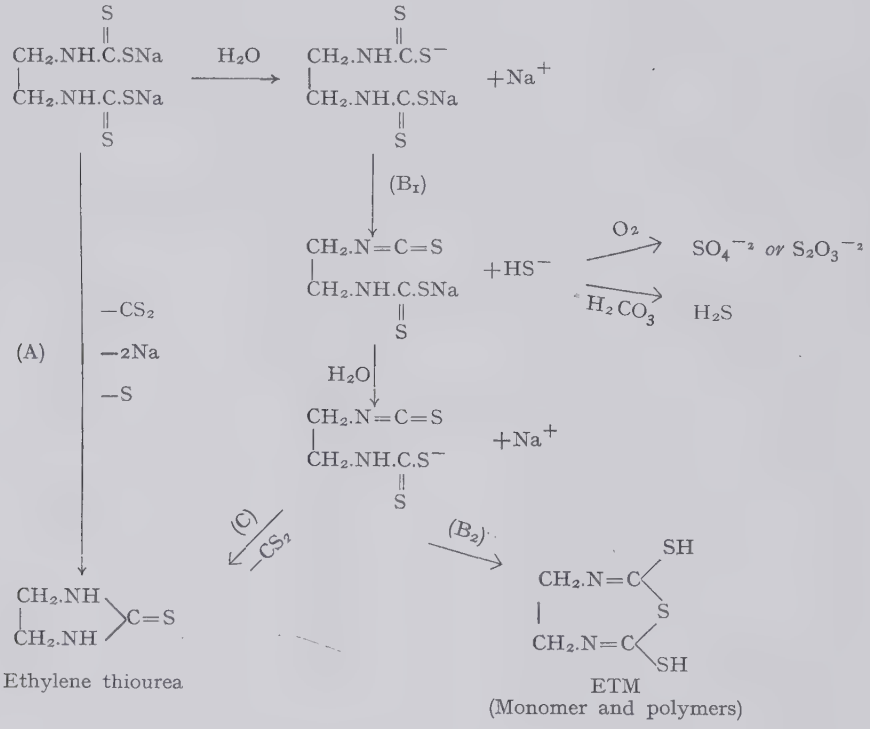
A 0·1 per cent w/v solution of nabam, carefully purified by recrystallization, as used in the preparation of products II 1 and II 4, was found to have a pH indistinguishable from that of the distilled water used. However, Thorn and Ludwig (1954) record a pH of 8·5, and Ludwig, Thorn and Unwin (1955) report approximately 10, for a similar concentration. It would, therefore, appear that the Canadian workers were using commercial samples containing impurities such as thiocarbonate and sulphide that would raise the pH of aqueous solutions. This alone would have an influence on the course of reactions. In the preparative work leading to products I 1(*a*), (*b*) and (*c*) and I 2, used in the tests reported here, tap-water solutions of a commercial, i.e. solid but not recrystallized, preparation were used ; the initial pH was 8·0–8·2, rising steadily during aeration to 10. When, however, a purified product was aerated in distilled water, the material I 1(*a*) was not formed and only a little of I 1(*b*) ; chloroform extraction of the filtrate yielded a product similar to I 1(*c*), i.e. ETM monomer, but still not in very good yield.

Lopatecki and Newton (1952) measured the uptake of oxygen and the evolution of gaseous sulphur compounds, using a Warburg manometer, when a dilute solution of nabam (0·036 per cent if the hexahydrate was used) was shaken with or without a phosphate buffer at pH 6. In the acid medium, both H_2S and CS_2 were evolved, the ratio being 1·2 : 1. In the unbuffered medium, only CS_2 was evolved, the pH rising from 7·3 to 10·5 ; but oxygen was absorbed in the ratio of 2·4 volumes per volume CS_2 evolved, i.e. oxidation of the HS^- ion occurred. Sulphite and thiosulphate were reported absent from the final solution, but sulphate was present. These workers, therefore, postulated that nabam decomposed in air to give ethylene thiourea (Barratt and Horsfall, 1947), carbon disulphide, hydrogen sulphide and caustic soda. In the absence of acid buffering, the sulphide was not evolved but was oxidized to sulphate ; no reason was offered why the pH should have finished at 10·5 if all the sodium hydroxide had been converted to sulphate.

Ludwig, Thorn and Miller (1954) postulate two processes for the breakdown of aerated nabam solutions ; both of these differ from the reaction proposed by Lopatecki and Newton. The second process they suggest would give a total yield of monomeric plus polymeric ETM of 70 per cent, based on anhydrous nabam ; in their balance sheet, only one-third of the original carbon appeared as ETM, the remainder appearing as equimolar yields of ethylene thiourea and CS_2. The first process proposed by these workers would provide no ETM, but the carbon would appear as ethylene thiourea and CS_2, the remaining sulphur being precipitated in the elemental form. In practice, they were unable to account for nearly 10 per cent of the sulphur, although admitting the possibility that it was present in the filtrate in an inorganic form as in the experiments of Lopatecki and Newton.

In the preparation of materials for the tests reported here, better yields of ETM were obtained by use of pure nabam, distilled water and oxygen, but usually not in excess of 45 per cent of the nabam

taken, based on nitrogen content. The remainder of the nitrogen appeared as ethylene thiourea. Approximately one-quarter of the sulphur, i.e. one atom per molecule of nabam, appeared as thiosulphate, and sulphate could not be detected ; sodium was also present in the filtrate as carbonate. These results are in harmony with the reactions proposed by Sijpesteyn and van der Kerk (1954) for the formation of ETM via an *iso*thiocyanate, and those proposed by Lopatecki and Newton (1952), except that thiosulphate and not sulphate was found. When crude nabam and tap-water, either with air or oxygen, are used, the first reaction proposed by Ludwig, Thorn and Miller (1954) would appear to explain the concomitant appearance of sulphur, as in product I 1(*a*) and in the Canadian G.D.26. These workers found sulphur in their precipitate equivalent to 5 per cent of the nabam taken ; this would imply that almost half the nabam had decomposed by route A, although this ' equation ' merely states the end-products and does not explain how free sulphur is formed. It is not clear why HS^- was oxidized to sulphate in the hands of one group of workers, and to thiosulphate in other hands. The amount of carbon dioxide present would influence the amount of HS^- left in solution to be oxidized, and hence the final pH which may be as high as 12. The various alternative processes so far demonstrated are combined in Fig. 1.



Key :
(A) Reaction A postulated by Ludwig, Thorn and Miller (1954).
(B_1) and (B_2) Reactions postulated by Sijpesteyn and van der Kerk (1954).
(C) Proposed reaction to account for formation of ethylene thiourea without appearance of elemental sulphur ; (B_1) plus (C) are equivalent to reaction postulated by Lopatecki and Newton (1952).

FIG. 1

Aeration or oxygenation of dilute (0·1 per cent) solutions of nabam

In general, these results confirm those obtained in Canada (Ludwig and Thorn, 1953 ; Ludwig, Thorn and Miller, 1954 ; Thorn and Ludwig, 1954). Such discrepancies as exist are likely to be due to differences in conditions of preparation, such as hardness of waters, and in purity of nabam samples used. The Canadian workers used *Sclerotinia fructicola* spores for most of their tests, and found thiram and chloranil to be inferior to the monomer, which had an ED_{50} of 1·5 p.p.m. It is not possible to state ED_{50} values for the organisms used in our tests, but it would appear that they would lie between 1 and 5 p.p.m. for *V. inaequalis*, and above 10 p.p.m. for *B. cinerea* even for the most active materials.

The lower toxicity of ethylene thiuram disulphide compared with that of the monosulphide towards both organisms is worthy of comment. In the case of open chain thiuram sulphides, the

disulphide, e.g. thiram, has always proved more active than the corresponding monosulphide (Montgomery and Shaw, 1943). This is in keeping with the view that the mechanism of action of alkylene bisdithiocarbamates differs substantially from that of dialkyl dithiocarbamates and thiuram sulphides (Sijpesteyn and van der Kerk, 1952).

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Summary

Materials obtained by aeration or oxygenation of dilute aqueous solutions of the fungicide, nabam, have been tested for toxicity to spores of the fungi, *Venturia inaequalis* (Cke.) Wint. and *Botrytis cinerea* Pers. *ex* Fr.

Products likely to be ethylene thiuram monosulphide and polymers were at least as active as captan, tested at the same concentration, towards *V. inaequalis*. Toxicity towards *B. cinerea* spores was much less, the reduction being greater than that exhibited by captan.

Ethylene thiuram disulphide was *less* active than the monosulphide, toward spores of both organisms.

Partial evaporation of a dilute nabam solution in shallow trays yielded a product as toxic as ethylene thiuram monosulphide, at least to *V. inaequalis*, but with a N : S ratio quite unlike the monomer or polymer.

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SOME OBSERVATIONS ON THE EFFECTS OF FORMULATION ON THE PERSISTENCE OF DDT AND ITS TOXICITY TO CERTAIN ORCHARD INSECTS AND MITES

By R. P. TEW and JOAN R. GROVES

Introduction

Recent field trials (Tew and Groves, 1956) have confirmed the marked superiority of DDT over lead arsenate and several other organic insecticides for the control of Codling Moth, *Ernarmonia pomonella* (L.). In these trials, increases in populations of the Fruit Tree Red Spider Mite, *Metatetranychus ulmi* (Koch), resulted from the use of insecticides, especially when DDT was used. It seemed possible that the mode of formulation of DDT might, through influence on its persistence, affect these two aspects of the Codling Moth problem. Emulsions and particulate dispersions offer two ways in which a water-insoluble pesticide, such as DDT, may be uniformly dispersed in an aqueous medium for hydraulic spraying. The orchard performance of representatives of these two types of formulation were, therefore, studied in two seasons.

Materials and layout

Field trial in 1953

The 1953 trial was carried out on a plot of twenty mature Cox's Orange Pippin trees on M.XII, which had been used in earlier trials and which was close to a packing shed (Tew and Groves, 1956). There were four replicates of five treatments, two being particulate dispersions and three being emulsions. All five were produced from commercially available preparations, details of which are as follows :

1. A 20 per cent wettable powder, comprising DDT-impregnated china clay and surfactants.
2. A 50 per cent DDT suspension in oil, comprising finely ground DDT suspended in an oil solution of surfactants.
3. A 15 per cent emulsion concentrate, i.e. a solution of DDT in a water-immiscible organic solvent already emulsified into water by the aid of surfactants and, therefore, requiring only further dilution to spray strength.
4. A 20 per cent miscible DDT, i.e. a true solution of DDT and surfactants in an organic liquid, from which the emulsion is formed on addition to water.
5. An 18 per cent ' activated ' miscible DDT, i.e. as (4), but containing an adjuvant claimed to increase biological activity and persistence.

All were used at rates corresponding to 0·1 per cent DDT and the sprays were applied on 26th June by a twin-nozzle lance, working at approximately 200–250 lb. per sq. in., from a 175-gallon tractor-drawn machine, care being taken to avoid drift.

Field trial in 1954

The 1954 trial was carried out on Cox's Orange Pippin and Worcester Pearmain trees, both on M.IX, on a plot also near a packing shed. Thirteen chemical treatments were used ; these were four particulate dispersions, three emulsions and six ' controls ' based on formulating chemicals alone. Four branches on each of thirteen trees of each variety were isolated by grease-banding at the bases, and the treatments were arranged over the 104 available branches in a basic design of balanced incomplete blocks. Details of the laboratory-prepared materials from which the treatments were made up are as follows (figures in brackets after components indicate their percentages in the final spray) :

A. A 20 per cent wettable powder—DDT (0·1), china clay (0·4) and saponin (0·015).
B. A 50 per cent wettable powder—DDT (0·1), china clay (0·1) and saponin (0·005).
C. A control for A and B—china clay (0·4) and saponin (0·015) only.
D. A 50 per cent suspension in oil—DDT (0·1), spindle oil (0·06), Triton X-100 (0·005), Triton B-1956 (0·005), and Aerosol OT (0·01).
E. A control for D—oil and surfactants only.
F. A 5 per cent miscible DDT—DDT (0·1), diacetone alcohol (2·0), MB320 (0·05), and Aerosol OT (0·01).
G. A control for F—solvent and surfactants only.

H. A 30 per cent miscible DDT—DDT (0·1), blend of water-immiscible solvents ('tar oil solvent' and 'heavy naphtha') (0·33), Triton X-100 (0·008), and Triton B-1956 (0·008).
I. A control for H—solvent and surfactants only.
J. A 30 per cent miscible DDT—DDT (0·1), xylene (0·33), and Triton X-100 (0·005).
K. A control for J—solvent and surfactant only.
L. A 30 per cent miscible DDT—DDT (0·1), 'tar oil solvent' (0·33), and Triton X-100 (0·005).
M. A control for L—solvent and surfactant only.

Recrystallized DDT (m.p. 106–109° C.) was used throughout. Triton X-100 is decaethylene glycol mono-*p*-octylphenyl ether; Triton B-1956, a phthalic-glycerol alkyl resin; Aerosol OT, the di-octyl sodium sulphosuccinate; and MB320, *cyclo*hexylamine dodecyl sulphate. 'Tar oil solvent' is a high boiling (225–300° C.) coal-tar fraction consisting mainly of methylated naphthalenes; and 'heavy naphtha' is a lighter coal-tar fraction (155–180° C.) made up of the lower homologues of benzene.

The sprays were applied on 1st July, by a twin-nozzle lance working at 60 lb. per sq. in. from a self-propelled 25-gallon machine, screens being used to prevent drift to branches receiving other treatments.

Field records

Codling Moth.—In 1953 a record was taken of the percentages of the total crops, both dropped and picked, which showed larval damage. In 1954, Codling Moth larval damage was at too low a level to show significant differences, and a record was not taken.

Anthocorid bugs.—In 1953, a beating record was taken, in which the fauna detached by tapping from six branches of each tree were collected and examined.

Mites.—Records were taken by counting the numbers of all stages present on a suitably sized leaf sample on a given date. Where numbers were low, direct counting was done; where higher levels were encountered, the imprint method (Austin and Massee, 1947) or the leaf brushing method (Henderson and McBurnie, 1943; Chant and Muir, 1955) was used.

Laboratory experiments

Chemical analysis

Residual DDT in leaf-samples taken on a given date was determined chemically by a modification of the Schechter-Haller procedure (Schechter *et al.*, 1945). Each leaf sample was air-dried and weighed, and extracted in a small beaker with three successive quantities of ca. 20 ml. benzene. The total benzene extract was clarified with approximately 1 g. of activated Fuller's earth (Grade 500 or 700) and filtered through a fluted Whatman No. 1 paper into a 150-ml. conical flask, the solid residue and the paper being rinsed with benzene. The solvent was removed with a current of dry air at 40° C. and the residue was nitrated for 10 minutes, on a boiling water-bath, with 2 ml. of a mixture of equal volumes of fuming nitric ($D = 1 \cdot 5$) and concentrated sulphuric acids. After cooling this solution to about 50° C. and diluting with 10–15 ml. water, the 'tetranitro-DDT' present was recovered by two extractions with 4 ml. benzene. This benzene solution was washed twice with 5 per cent aqueous potassium hydroxide solution and once with water, dried by passing through 1–2 g. of anhydrous sodium sulphate supported by cotton wool in a small filter-funnel, and made up with benzene to a final volume of 10 ml. Aliquots were taken for colour development with 5 per cent ethanolic potassium hydroxide; colour measurement was made on a Spekker photoelectric absorptiometer at a wavelength of 600 mμ. A calibration graph, prepared by adding known amounts of DDT to unsprayed leaves and following this procedure, was used to calculate the residue data.

Tests of residual toxicity

In 1953, leaf samples, three from each tree, were placed in petri dishes and 5 or 10 Tortricid larvae, usually *Adoxophyes orana* (F.R.), but occasionally *Pandemis heparana* (Schiff.), were placed thereon and left for three days, after which dead and live larvae were counted. In 1954, glass jars, each closed by muslin and a cork-ring, were used in place of petri dishes, ten larvae being used in all tests.

Results

The field and laboratory data were submitted to statistical analysis by methods appropriate to the design of the trial and the nature of the record.

Field data

In general, there was little evidence from the insect records of differential effects due to the mode of formulation of the insecticide. Codling Moth itself proved no guide, on account of large tree to tree

variations in 1953 and a too low level of attack in 1954. The Anthocorid record in 1953 (Table I) was also no guide to differences, but at least revealed that the DDT still present in August was by no means toxic to the point of extinction of this insect species. Predatory insects were not observed in important numbers during the 1954 trial.

TABLE I

FIELD RECORDS OF CODLING MOTH DAMAGE AND OF THE INCIDENCE OF FRUIT TREE RED SPIDER MITE, TYPHLODROMID MITES AND ANTHOCORID BUGS IN THE 1953 TRIAL

Organism and record	Suspensions		Emulsions		
	1 from wettable powder	2 from suspension in oil	3 from 'emulsion concentrate'	4 from 'miscible oil'	5 from 'activated miscible oil'
Codling Moth : Percentage of total crop damaged	24·1	13·9	10·0	10·0	15·4
Fruit Tree Red Spider Mite : Average number of all stages on 24 leaves on 18th August ..	2,262	3,028	2,108	2,414	3,081
Ratio of eggs to mites on 18th August	0·6	0·7	1·3	1·0	0·8
Average percentage of defoliation on 14th September ..	15	25	40	30	24
Typhlodromid mite : Average number on 48 leaves during 26th August to 4th September	40	28	9	3	3
Anthocorid bug : Total number released by beating on 25th August ..	53	56	31	41	42

Figures within brackets do not differ significantly (P = 0·05).

Mite records in both years were specially interesting. In 1953 (Table I) no differences due to treatment were apparent from the record of all stages of the Fruit Tree Red Spider Mite present on 18th August, but on this date treatments 3 and 4 had most trees with badly-bronzed leaves and treatment 1 the greatest number of trees with green leaves. These differences were also apparent from the defoliation record on 14th September, trees in treatment 1 showing very little leaf-fall or bronzing, those in treatment 2 and 5 rather more, and all trees in treatments 3 and 4 being severely defoliated. Fruit Tree Red Spider Mite records in 1954 (Table II) clearly demonstrated that the observed increases in populations of this species were due to DDT; steady increases in populations on treatments containing DDT led to highly significant differences (P = 0·01) between all these treatments and their 'formulation controls' by the end of the season. Except for treatment A, these differences were already apparent, at lower levels of significance, by 16th August, and existed at 22nd July for treatments D and H, the controls for which, E and I, carried such low levels. On 4th October, higher mite populations were detectable on emulsion-sprayed, than on suspension-sprayed branches, the significant differences here being :

B	D	A	F	J	L	H	
11	16	25	81	85	96	186	(P = 0·01)

On the controls, the opposite effect was observed, there being significantly more mites (P = 0·05) on the 'suspension' than on the 'emulsion' controls at both the first and the second sampling occasions :

	'suspension' controls C + E + G	'emulsion' controls I + K + M
22nd July	19	8
16th August	37	16

Table II

Field records of the incidence of three species of orchard mites in the 1954 trial

		Suspensions							Emulsions						
		A	B	C	D	E	F	G	H	I	J	K	L	M	
		from 20 per cent wettable powder	from 50 per cent wettable powder	formulation control	from 50 per cent oil suspension	formulation control	from diacetone alcohol and surfactant	formulation control	from ' mixed solvent ' and surfactant	formulation control	from xylene and surfactant	formulation control	from ' tar oil ' solvent and surfactant	formulation control	
Fruit Tree Red Spider Mite	22nd July	17	48	33	34	7	24	29	60	6	26	9	28	10	
	16th August	142	263	45	234	20	234	57	489	15	281	21	309	13	
	4th October	23	11	0	16	1	81	1	186	0	85	0	96	0	
Bryobia Mite	22nd July	0	4	2	7	3	1	2	2	0	0	0	0	0	
	16th August	5	25	5	33	7	9	1	14	2	3	3	2	3	
	4th October	5	10	1	30	5	6	0	14	0	1	0	1	1	
Typhlodromid Mite	22nd July	1	0	16	1	12	0	6	0	2	0	4	0	5	
	16th August	0	3	8	2	9	0	2	0	5	1	6	0	8	
	4th October	2	4	0	5	5	2	4	2	0	0	2	2	7	

The figures are re-transformed mean numbers of all stages present on 24 leaves.

A similar, but less clear picture emerged from a study of the Bryobia records (Table II) ; here significant differences (P = 0·05) existed at the final sampling only. Thus at the end of the season all treatments except A, J and L carried higher numbers of mites than their formulation controls. Here, however, there were no significant differences between the levels on ' suspensions ' and ' emulsions '.

The Typhlodromid mite record at the end of August 1953 (Table I), showed that this DDT-susceptible mite (Clancy and Pollard, 1952) was present in larger numbers on foliage sprayed with suspensions of DDT than on that sprayed with emulsions. It was, in fact, this difference in toxicity of residues of DDT from these types of formulation to a suspected predator of the Fruit Tree Red Spider Mite that decided the approach to and design of the 1954 trial. The results obtained in 1954 (Table II) confirmed the susceptibility of Typhlodromid mites to poisoning with DDT, all treatments differing significantly from their controls (P = 0·01) at the first sampling. Re-establishment to higher levels on the suspension-sprayed than on the emulsion-sprayed foliage was not demonstrated. Significant differences between the DDT treatments and their controls had disappeared completely by the date of the final sampling due mainly to decline in the population on the controls. As with the Fruit Tree Red Spider Mite, significantly more Typhlodromid mites (P = 0·05) were found, at the first sampling, on the ' suspension ' controls (C + E + G) than on the ' emulsion ' controls (I + K + M), re-transformed means for these groupings being, respectively, 10 and 3.

Laboratory data

The residue data obtained by chemical analysis in 1953 (Table III) showed that very similar initial deposits of DDT were left by all treatments, but that those from suspensions were less persistent than those from emulsions. Although this broad picture was confirmed in 1954 (Table IV), it was obscured to a considerable degree by the very low initial deposits present at the first sampling on the suspension-sprayed branches. An interesting and important observation in 1954, however, was that treatment F, in which DDT was precipitated as fine crystals on dilution of the water-miscible concentrate to spray strength, was much more akin to the emulsions, both in initial deposit and in persistence, than to the solid dispersions. These observations were confirmed by the mortalities of Tortricid larvae exposed to sample leaves (Tables III and IV). These differences between deposits from suspensions and emulsions are clearly demonstrated when the respective chemical residue data and

TABLE III

DDT DEPOSITS (IN PARTS PER MILLION OF DRY WEIGHT) ON LEAVES, AND MORTALITIES AMONG TORTRICID LARVAE PLACED THEREON (1953)

Date of sampling	Suspensions				Emulsions					
	1 from wettable powder		2 from suspension in oil		3 from ' emulsion concentrate '		4 from ' miscible oil '		5 from ' activated miscible oil '	
	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae
26th June	—	79·0	—	94·5	—	94·5	—	100	—	93·0
27th June	480	—	385	—	385	—	422	—	480	—
8th July	—	100	—	65·0	—	94·5	—	94·0	—	94·5
14th July	190	—	190	—	275	—	285	—	308	—
15th July	—	63·0	—	82·0	—	95·0	—	84·5	—	100
13th August ..	—	57·5	—	42·5	—	76·0	—	32·0	—	76·0
17th August ..	—	26·0	—	51·5	—	50·0	—	56·0	—	47·0
24th August ..	67	—	120	—	142	—	180	—	200	
28th August ..	—	32·5	—	17·0	—	40·5	—	39·0	—	17·0

Among the chemical data, means within brackets do not differ significantly (P=0·05).
The mortality data were not suitable for statistical analysis.

Table IV

DDT deposits (in parts per million of dry weight) on leaves, and mortalities among Tortricid larvae placed thereon (1954)

Date of Sampling		Suspensions								Emulsions					
		A from 20 per cent wettable powder		B from 50 per cent wettable powder		D from 50 per cent oil-suspension		F from diacetone alcohol + surfactant		H from 'mixed solvent' + surfactant		J from xylene + surfactant		L from 'tar-oil solvent' + surfactant	
		DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae	DDT	Mortality of larvae
8th July	Cox	168	—	76	—	103	—	445	—	455	—	494	—	494	—
	Worcs.	32	—	41	—	123	—	146	—	219	—	300	—	392	—
16th July		—	86·5	—	92·0	—	95·0	—	100	—	96·0	—	97·5	—	91·5
4th August		—	54·0	—	79·0	—	50·0	—	100	—	100	—	93·0	—	91·5
5th August	Cox	98	—	65	—	54	—	157	—	130	—	163	—	212	—
	Worcs.	46	—	46	—	46	—	114	—	82	—	127	—	132	—
11th August		—	47·0	—	39·0	—	55·0	—	97·0	—	76·5	—	82·0	—	100
9th September	Cox	98	—	49	—	49	—	130	—	135	—	114	—	141	—
	Worcs.	50	—	36	—	41	—	109	—	64	—	82	—	127	—

Among the chemical data, means within brackets do not differ significantly (P = 0·05).
The mortality data were not suitable for statistical analysis.

larval mortality figures are plotted to show change with time, data for treatment F in 1954 being included with those for the emulsions (Figs. 1 and 2). Plotting of the DDT residue data on a logarithmic scale against time (Fig. 3) emphasizes the difference in persistence between suspensions and emulsions in both years and the unsatisfactory performance of the solid dispersions used in 1954.

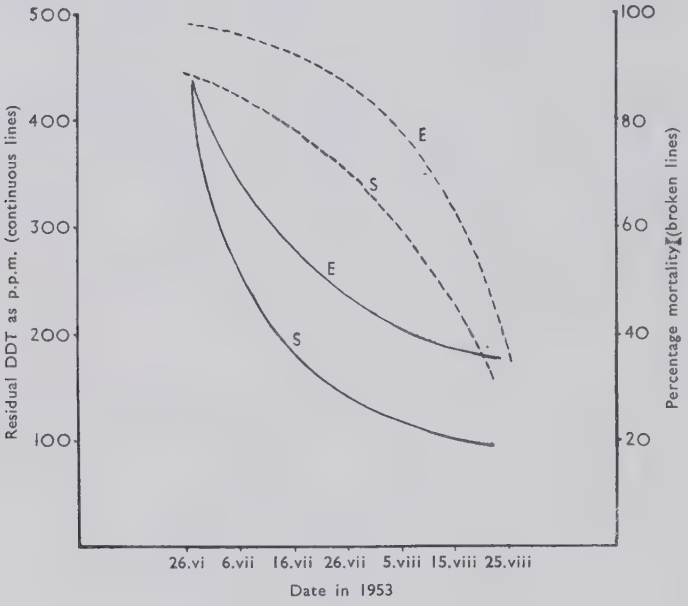

FIG. 1

Diagram showing decline in magnitude and in toxicity to Tortricid larvae, of DDT deposits from suspensions (S) and from emulsions (E), in 1953

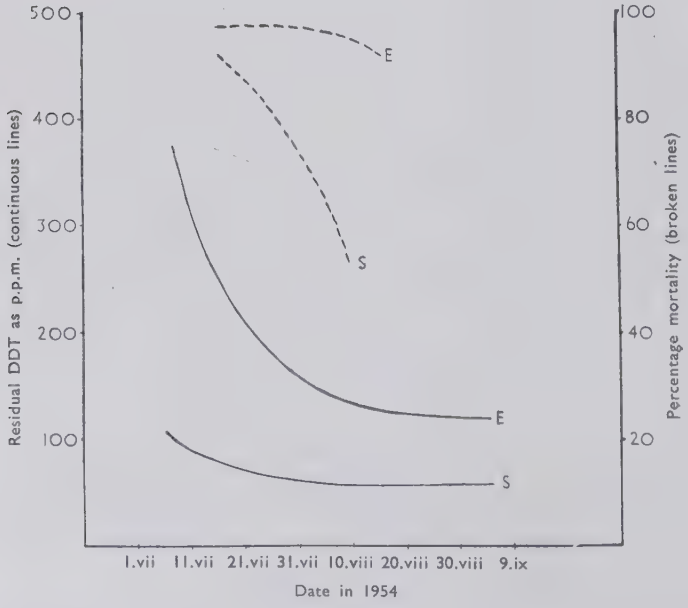

FIG. 2

Diagram showing decline in magnitude, and in toxicity to Tortricid larvae, of DDT deposits from suspensions (S) and from emulsions (E), in 1954

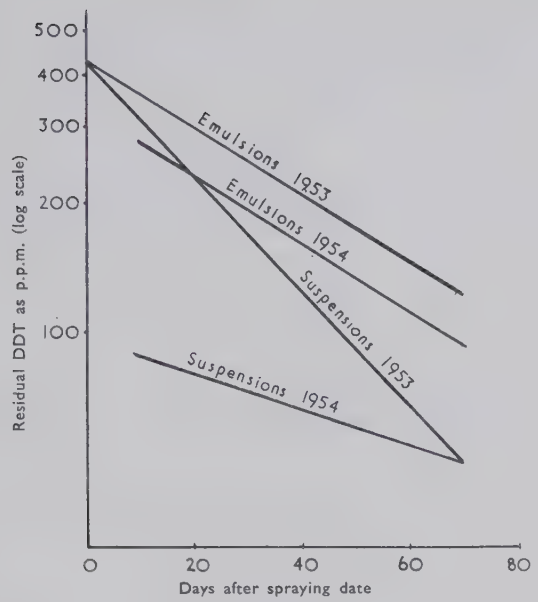

FIG. 3
Persistence of DDT deposits in the two years

Discussion

The field data have provided clear evidence of

(i) the toxicity of DDT to Typhlodromid mites,
(ii) an association between DDT applications and the development of high populations of the two species of phytophagous mites,

and somewhat less evidence that

(iii) the mode of formulation may influence these properties.

The laboratory data have revealed differences in persistence of deposits from the ' suspension ' and ' emulsion ' formulations.

In 1953, both Typhlodromid mites and Anthocorid bugs were recorded as present in the orchard and the occurrence of larger numbers of the former on trees which showed less injury from the Fruit Tree Red Spider Mite was taken as evidence of predation by this mite species. In 1954, its virtual destruction by DDT could again be adduced in support of this hypothesis. Precise laboratory work has, however, now cast doubts upon the value of Typhlodromid mites as a natural control agency for phytophagous mites (Chant, 1956). Predation by insect predators such as *Blepharidopterus* spp. was not observed so that one is obliged to consider the possibility of an indirect effect of DDT by some other mechanism or direct stimulation of the mites by the insecticide itself. Considerable interest then attaches to the second and third conclusions above in relation to the decay of the insecticide deposits through the season. An increase in fecundity of the Fruit Tree Red Spider Mite under the influence of DDT has already been claimed and its association with certain critical dosages of insecticide postulated (Hueck *et al.*, 1952). The different population levels of this mite observed in the 1954 trial could well reflect different ' levels of stimulation ' by deposits of DDT of different magnitude, location and form. In 1953, the ratios of eggs to mites on 18th August (Table I) point to similar differences. In general, the possibility that a way may be found to reduce the undesirable side-effects of the valuable Codling Moth insecticide, DDT, has received some support from the work reported here.

Summary

Two seasons' trials have been conducted with various formulations of DDT, applied primarily for control of the Codling Moth, *Ernarmonia pomonella* (L.) on apple. Large tree to tree variations (1953) and a low incidence (1954) of this pest prevented assessment of the relative merits of the various formulations.

The increases in phytophagous mite populations which occurred in these trials have been shown, by the use of formulation controls, to be due to the DDT applied. The results suggest a mechanism

other than removal of control by predatory insects, which were not abundant, or mites, which may be unimportant. The higher levels reached on trees sprayed with DDT emulsions compared with those on trees sprayed with suspensions were probably reflections of the greater persistence of DDT deposited from emulsions than from suspensions as shown by periodic chemical analysis of residues and by laboratory bio-assay using Tortricid larvae.

Pronounced contact toxicity of DDT to Typhlodromid mites was observed ; smaller numbers of this mite were present in late summer on trees sprayed with emulsions than on trees sprayed with suspensions. This may also reflect the differences in residue levels.

DDT dissolved in diacetone alcohol with surfactants and subsequently poured into water to form a suspension of fine crystals behaved more like the emulsion used than like the other particulate suspensions.

Acknowledgements

The authors wish to acknowledge the help given by Mr. D. A. Chant, who assisted in taking the mite records in both years, Miss W. M. Phillips, who performed the chemical analyses in 1953, Miss M. Bennett who advised on and assisted in taking bronzing and defoliation records in 1953, and Miss P. Webb who applied the sprays in 1953.

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Part IV

BULLETINS FOR FRUITGROWERS

RESEARCH AND THE PROBLEM OF APPLE SCAB CONTROL

By M. H. MOORE

Almost everywhere that apples can be successfully grown, this destructive fungus disease is a recurring problem, and yet it has hitherto been the subject of far more research and experimental work than probably any other disease of fruit crops. There is a truly formidable record of investigation in the literature, as any reviewer knows to his cost. Why then must the fruit-growing industry still be plagued by this menace ; cannot it be controlled ? Do we need to know still more about it before we can stamp it out ?

It certainly is a curious situation on the face of it, and the reasons cannot be given in a sentence. The writer will, however, attempt to explain at least some of them, and then touch on methods of approach to the problem of field control, other than by conventional protective spraying, that have been or are being investigated.

The problem of control

To offset any feeling of frustration that the opening remarks may have engendered, it must be emphasized that Scab can be well controlled. Some growers have known this for years, and others discover the truth of it as their experience broadens. Some, indeed, have said that we should not make it too easy or there will be no skill left in apple-growing ! Be that as it may, the majority of growers would doubtless like to feel more confident about success every year than they probably do now. Therein lies much of the problem ; one is never quite sure that the chosen spray programme will always give a satisfactory answer in any circumstances that may arise, and sometimes there is a resort to emergency measures that might have been better avoided.

To frame control measures intelligently for any fungus disease, it is essential first that the structure of the fungus, its seasonal development, and the manner in which its spores are produced and distributed should be studied and understood. This is the task of the mycologists and plant pathologists, and we are fortunate with Scab, for this has already been done and the results recorded by many pioneer investigators in different parts of the world. There is, moreover, general agreement among them, with perhaps divergence on points of detail here and there. The broad outlines have often been stated, and are by now well known to many growers, but it may be helpful to recall them here as a framework for later comments.

The fungus

(a) Sources of spores

Infected apple leaves lying on the ground throughout the winter produce spores (ascospores) in vast numbers in spring and early summer. Infected young shoots of ' wood '-susceptible varieties carry little cushions of Scab fungus over winter beneath the bark. In spring the overlying bark splits exposing the cushions, which produce spores of a different kind (conidia) on their surfaces. Some varieties are known to carry these cushions also in or on the buds ; they have been found, for instance, on Bramley's Seedling, which, however, unlike Cox's Orange Pippin, does not carry shoot-infection.

It will be appreciated, therefore, that this fungus is well equipped to survive and flourish ; it keeps going in spite of an annual loss of legions of spores that never reach a target, or are destroyed by fruit-growers' efforts if they do. During winter, the fungus can withstand severe weather and is well protected from surface-acting sprays ; in fact the only certain way to destroy the spore-producing centres is to destroy all the leaves or the shoots and buds that bear them. To do this completely is far from easy, though the numbers of centres can be reduced in various ways, of which more will be said later.

(b) **Release and dispersal of spores**

Ascospores, when mature in spring, are shot out a short distance (not more than about half an inch) from the dead leaves, and then whirled by air currents into the prevailing wind, by which they are carried amongst the trees. Their presence in the orchard air has often been demonstrated by investigators who have trapped them in various ways. The mechanism for ejecting the spores is set into action when the dead leaves are made thoroughly wet. Mature conidia from twigs and buds, though not ejected, are readily released in water, but are not readily detached without it. Most of the danger from them is therefore likely to be confined to the tree on which they occur, by localized distribution through the splashing and flowing of rain ; this is true also of conidia produced by new infections (whether from ascospores or conidia) already established on foliage and fruit.

Thus, in broad terms, ascospores chiefly extend infection throughout plantations ; conidia chiefly build it up on individual trees.

Ascospores are regarded in most apple-growing areas as the main source of new infections in spring, and it is chiefly against them that spring spraying is directed, though conidia from shoot infection must obviously be taken into account if much of it is present. Until recently, conidia had been regarded as possibly the more important source in the Wisbech area. For the past few years, however, the Plant Pathology Department at Rothamsted, with the Wisbech N.A.A.S. staff, have recorded the numbers of ascospores caught in power-operated suction-traps erected in Wisbech orchards. Meteorological conditions also were continuously recorded by instruments sited near the traps, so that the relationships between spore-dispersal and infection and the weather conditions could be assessed. The results demonstrated conclusively that ascospore flights from March until June over several successive seasons were primarily, if not entirely, responsible for early outbreaks of Scab in that area also. Similar investigations now extended to other areas will provide a basis for comparison.

Ascospore flights are closely related to rainfall, assuming of course the presence of mature spores in the dead leaves, but it is interesting that some investigators largely discount dew as a triggering agent. Dew sufficient to wet these leaves thoroughly should release the spores, yet few might become airborne while much surface water persists ; the spores are more likely to be submerged after ejection from the spore cases. Such interference with the normal mechanism of dispersal is especially likely at night when the rate of evaporation is low or nil. In the Wisbech experiments it was observed that ascospores were, in fact, less likely to be caught in the air during the night than during the day. Moreover, in daylight catches there was often a time-lag of two or three hours between the onset of rain and maximum catch—a fact that could be regarded as reflecting the rate of evaporation of the surface water overlying the spore-cases. Large catches might thus be expected to result from a few fairly heavy showers, with intervals for drying-off excess surface water, on rather warm or possibly windy days of low humidity (e.g. ' April ' showers). In the event, small daily total amounts of rain do sometimes yield disproportionately large catches. Several hours, and certainly days and nights, of continuous rain would cause many spores to be submerged, as with persisting dew, and would, in addition, wash the air free of many more that had contrived to become airborne.

Mature ascospores can be found in the fallen leaves even from January till June, but any that are released before the buds burst have no susceptible target, and can therefore be ' written off ' from the growers' point of view.

Infection

The requirements for infection of susceptible leaves and fruits depend closely upon temperature and moisture. The extensive investigations recorded during the first quarter of this century on this and the foregoing allied subjects were reviewed in the Station's Annual Report for 1928–30, pp. 157–76. It was established that the spores germinate and start to infect most rapidly at around 68° F. provided enough water is present for a long enough time to enable them to do so. More recent work in the U.S.A. and elsewhere has confirmed and emphasized these early findings. The results of such investigations can be summarized as a convenient table or chart showing the periods of continuous leaf-wetness necessary for infection at differing temperatures (' infection periods '), and growers will now be familiar with the ' Mills Chart ', so styled after its author in the U.S.A. As the temperature recedes appreciably from, or indeed rises much above, the optimum 68° F., so is the infection process slowed down, and thus a longer period than the 9 hours minimum of leaf-wetness is necessary for it to take place. A practical difficulty in the plantation is the absence of any certain way of determining how long the leaves have been wet, but experiments to develop a satisfactory self-recording instrument are well advanced in Holland and, in this country, at Rothamsted, where Potato Blight, a disease similar in many of its requirements to Apple Scab, is being investigated on similar lines. It will, however, be apparent to growers that a fruit tree, mainly by reason of its greater height and spread,

may present an even more complex problem than a potato plant in exhibiting varying rates of drying after rain or dew. Thus it will be possible—growers will have noticed it in their plantations—for some leaves and fruits to retain surface moisture long enough after the rest are dry to permit at least light local infection to occur. ' Pin-spot ' Scab in the eyes of some pears (especially Conference) and pendulous apples may well be an example of it. This local variation may apply to some parts of the farm more than others because of the lie of the land and the effect of shade, shelter, and such-like. It must be emphasized that dew may persist during cool nights after warm days in late spring and early summer, and it could therefore contribute an important part to the duration of the leaf-wetness necessary for infection at a critical period of the season for Scab. The early finding is also worth recalling here—a point sometimes overlooked—that brief periods of drying during the general extent of leaf-wetness do not hinder infection, and probably help it by ensuring that the spores become fixed to the leaves. While rain continues, many conidia will be distributed over the tree from any infections already established upon it, though these spores may have no chance to settle before they are washed away ; moreover, as already stated, numerous ascospores that are released by the rain may never even arrive on the tree during such conditions.

Meteorological investigations in Holland have shown that agreement between visual observations of the duration of periods of general leaf-wetness and the expectation of their duration from instrument readings at weather stations is reasonably good, and that these station-reports, and especially those from near the fruit-growing area concerned, can often give reliable guidance to Dutch fruit-growers who desire to use post-infection sprays. In the hilly areas of Britain there may be added local complications, but these matters are under investigation by meteorologists in this country in respect of both Potato Blight and Apple Scab. It would be a great advance indeed if as a result of such investigations the imminence of infection periods could be reliably forecast to enable growers to protect their trees beforehand, but this is asking a great deal in an island country that sustains a rueful joke about its capricious daily climate.

Control by protective spraying

A protective spray is applied to leaves and fruits before spores alight on them, and it acts as a surface to ward off infection. This method of control of fungus diseases is traditional in plant pathology, and has been the mainstay of Scab-control. It will be obvious from what has already been said about spore-dispersal and infection that correct timing of suitable sprays and thoroughness of application must be the basis of successful use of this principle. Failure to appreciate this or to put it into practice has been the cause of most disappointments, though it is only fair to add that until comparatively recently the grower was considerably handicapped by the limits imposed by available spray-machinery. Before the 1939 war, most equipment was incapable of rapid enough work to avoid overlong intervals between successive sprays, thus leaving much new growth unprotected. Present machines leave little to be desired in this respect, and the chief problem now is to combine speed in spraying with good coverage.

(a) **Methods of spraying**

The improvement in spraying machinery and methods, reviewed in the Station's Annual Report for 1948, pp. 153–6, was without doubt the most telling single development in our progress towards mastery of Scab in the field, simply by greatly increasing the speed of the spraying process. No longer need the excellent results often obtained by well-timed protective sprays on the experimental plot be regarded as beyond practical achievement on the farm. Timing and thoroughness of application could be as good with the one as the other ; farm and plot were at last on something of an equality, and this has since been clearly demonstrated by the results of various orchard spray competitions. Scab can be, and is being, well controlled even on large holdings. The peak of attainment was probably reached fairly late in the ' hydraulic era ', but the volume of spray necessary to achieve it called for large-capacity pumps, powerful engines, and above all, large tanks for the spray. It soon became clear that we were fast approaching an impasse, as the water supply did not match the machinery. It was ridiculous that speed in spraying should, after all this, be limited by the time taken to fill the spray-tank. Various devices for quick filling were developed, but they served only where there was enough water to warrant them.

We have thus reasoned our way towards low-volume spraying, and, somewhat paradoxically, in doing so have returned a long way towards the starting point, for the pioneers of spraying in the early days also sprayed at low volume, and often with fairly concentrated sprays. But they had to ; their machines could do nothing else, and it was a slow process. The delivery of spray at low hydraulic pressure through small nozzle-orifices demanded only fairly small volumes of liquid, which were of necessity broken up into what we should now regard as a relatively small number of fairly large

droplets, and distributed with difficulty. By contrast, the present-day objective is to break up, and distribute automatically, an even smaller volume of liquid into a large number of very small droplets by the economic use of air rather than of hydraulic pressure. Modern low-volume machinery is skilfully designed to that end, and much engineering and biological research has been stimulated towards improving it further, for the new approach demands fresh standards of efficiency. The dripping tree is no longer the acme of spraying perfection—today we take a hand-lens to look for the deposit. What is the best kind of deposit and the best way to achieve it ? We have the old questions in a new setting, for the principles of control by protective spraying have not changed. Research and experimental work directed towards a solution of the many problems inherent in these two questions is now virtually world-wide, and includes contributions from Long Ashton, the N.I.A.E., and several other already well-known sources in this country, where low-volume methods are being quickly taken up. Evidence as to the merits and demerits of these methods in practice is now beginning to accumulate rapidly. It is doubtful whether Scab control is quite as good as it was at the peak period already mentioned, but some decline is perhaps to be expected until the new methods are well understood and have been assimilated into normal farm practice. Continuing improvements in machinery for low-volume spraying will doubtless accelerate our progress in this field, as with hydraulic spraying earlier.

(b) **Fungicides**

While better spraying methods were responsible for greatly improved Scab control, spray damage from the older copper and sulphur fungicides tended to increase with increase in volume and delivery pressure. For many years research had been in progress to find safer fungicides, and the choice was broadened by the introduction of new types of chemicals, already discussed in the Station's Annual Report for 1954, pp. 152–4. Captan matches the older materials in protection against Scab, and causes little or no damage, though it fails completely against Apple Mildew. Few of the other new materials show much improvement in this respect, and in attempting to solve the problem of spray damage we have exposed another, for Mildew was rarely troublesome when sulphur sprays were invariably used against Scab. This situation has stimulated much research on specifics for Mildew control, though so far only a costly crotonate compound has shown any real promise in the field.

Certain mercury compounds have long been well known as seed disinfectants, and some fifteen years ago a field investigation was begun at East Malling of phenyl mercury chloride, an allied compound, as a foliage protectant for fruit trees. Laboratory investigation had shown it to be the best of various mercury compounds that were powerfully active in preventing the germination of Scab conidia on glass slides. Phenyl mercury chloride maintained this promise as a protectant against Scab in the field, but sometimes, and especially in wet weather, damaged Cox's Orange Pippin and, more recently, has been shown to damage some pear varieties also. Nevertheless, a larger range of phenyl mercury compounds is available now, and their use is firmly established in practice, especially for Bramley's Seedling.

Control by spraying after infection

(a) **After freshly-established infection**

It is not as protectants, however, that mercury sprays tend now to be primarily regarded, for it has been shown in other countries, and demonstrated particularly in the Wisbech area in this country, that these sprays are able to prevent development of an infection if applied within a few days after this has occurred ; the less the interval, the better the result.

It will be appreciated that to rely on this post-infection method of control does not permit of any relaxing of standards of spray coverage ; indeed, coverage should be even better than by protective spraying, for to eradicate demands contact between fungus and fungicide without delay, while to protect allows more time for effective redistribution of chemical, during the weathering process, to any parts of leaves and fruits missed in the spraying.

In field experiments it is not always possible to separate the two actions by results. Especially where infection periods occur at intervals of only a few days, some forward protectant action is likely from a spray applied soon after any one such period. To determine just how long after infection an eradicant spray can be effective, and to rule out any possibility of confusion with protectant action, specially designed experiments are desirable, preferably in the greenhouse, and these are in progress at East Malling and elsewhere. Meantime, growers can profit from the knowledge that another approach to Scab control is available to them, though it is debatable whether or not it is prudent to adopt it to the exclusion of protectant sprays rather than as an added safeguard in emergency for varieties that tolerate mercury. There is something disturbing in knowing, or at least having reason to believe, that infection has already taken place. Farm routine will, as always, settle down in time to a satisfactory practical answer that must clearly be conditioned by the circumstances of each case ; for

example, by the varieties grown and the seasonal conditions prevailing, and not least by the economics of the choice.

(b) After long-established infection

This principle is the basis of the so-called ' floor spraying ' of the U.S.A. The idea is to prevent the formation and release of ascospores, thus breaking the main connecting link between any one season's infection and that of the next. Spraying the fallen leaves with mainly DNC preparations has been practised in the U.S.A. since the early nineteen forties. Experiments have shown that the numbers of ascospores available for infection can by this means be substantially reduced, so that the normal spray programme the following year has a lighter task, though it cannot be dispensed with. An obvious practical difficulty in achieving thorough contact with all fallen leaves will largely govern the success achieved. More recently, promising experiments on the same principle have been reported from Australia, but the leaves in this case were sprayed in autumn while still on the trees. A phenyl mercury chloride preparation was the most successful of the materials tested, including DNC, but at the strengths experimentally used it might prove costly on a field scale.

' Floor spraying ' clearly could not deal with overwintering shoot and bud infection, which is best removed in pruning, and it is unlikely that an autumn foliage spray, Australian fashion, would have much if any influence on it either. To warrant the use of these expensive methods the trees must have become sufficiently infected during the previous growing-season, which suggests that normal spraying failed and could be improved. Nevertheless, such things sometimes happen, and in a concentrated fruit area co-operative measures along these lines among neighbouring growers anxious to reduce local ascospore populations would doubtless be helpful to all the participants. This contention applies equally, however, as things are now, for growers adopting sound spring and summer programmes are already helping to fend off the cumulative effects of the disease in their own community. Numerous unsprayed trees in private gardens add to the numbers of ascospores in the air, but it would clearly be difficult to assess with any accuracy the potency of this uncontrolled factor in the economy of commercial spraying. The Rothamsted spore-trap experiments, and especially those in relation to ' floor spraying ', may nevertheless help to throw some light on the likely effective range of ascospores.

The present position

So far, the problem of Scab control has been reviewed in relation only to protective and post-infection spraying. The point has been made that, ideally and indeed in practice, conventional protective spraying can solve the problem. That it does not always do so, in spite of much intensive and extensive research, suggests that the reasons lie mainly in practical difficulties met with in applying the findings of research. Some past difficulties have been greatly mitigated in course of time by improvements in spray machinery and methods, and by the introduction of new chemical sprays, but even so, growers are sometimes still faced with seasonal conditions that militate against even the best husbandry. Spray programmes that seem quite sound on paper may occasionally give disappointing results in practice, and, where the spraying is above reproach, the failure can usually be traced to interference with the timing of sprays by adverse weather conditions. There is a strong inducement to ' tinker ' with the programme, to fall for some perhaps passing fancy, and after a time the fundamentals may tend to become obscured by a legion of complicated side issues. There seems indeed to be little cause to fear that the skill will depart from apple growing because things have become too easy ! Rather have we all reached a stage of wondering more urgently than hitherto whether there is not some better way of approach to Scab control, with more certainty and less pitfalls. Can we not in some way by-pass these twin obstructions, correct timing of sprays and thoroughness of cover ?

There are possible ways round ; none is likely to be free from pitfalls, and each will entail long-term fundamental studies, some of which have already been in progress for many years in different parts of the world. Meantime, there is no immediate prospect of profitably abandoning the conventional methods, which have served us well.

The problematic future

(a) Systemic fungicides

The successful use of certain systemic insecticides has naturally drawn attention to the possibility of using the same principle for fungicides. This principle is based on absorption by the plant of suitable chemicals (applied to it in some convenient way) that are thereupon taken into its system and carried to young growing tissues liable to be attacked by pest or disease. If the idea could be made to work an immediate advantage is apparent, for, with the fungicide distributed by the plant within itself, the problems of timely and thorough distribution from outside, inherent in control by

the surface-acting spray, would no longer arise. Scab spores, for instance, would be killed, or at least prevented from normal growth during the infecting process, by a fungicide already present within the susceptible host tissues.

It is easy to be carried away with enthusiasm for such an attractive prospect when merely stating the basic idea, but nevertheless there is now evidence from the continuing patient work at several research centres in this and other countries that the idea is more than just fantasy. A few rather complicated groups of chemicals are already known to offer possibilities. Antibiotics, for instance, are natural products of the growth processes of some fungi and bacteria ; streptomycin used against bacteria and griseofulvin against fungi are antibiotics derived from groups of the lower fungi. Fruit trees also contain chemical agents, sometimes called the natural inhibitors, that are an essential part of the mechanism of disease resistance, of which more will be said later. Then there are the growth-regulating agents or hormones, some derivatives of which have shown possibilities as systemic fungicides in investigations at Wye College.

Mention of a few of the difficulties that have already been encountered may be a timely corrective to any natural impatience for ready practical applications. It has been shown that griseofulvin, for example, may be distributed variably, if at all, in differing kinds of plants, and that when it is distributed any effect it may have in reducing disease tends gradually to fall away. Thus more than a single application over a long growing-season may prove necessary to maintain effectiveness. Moreover, antibiotics tend to act more efficiently when taken up by the roots than when sprayed on to the foliage, which sets a problem in terms of a fruit tree. Some chemicals, even if they are readily distributed to the parts of the plant liable to become infected, may cause direct or indirect damage to the host cells. The problem is somewhat different with systemic insecticides ; it is easier to conceive of materials toxic to insects but innocuous to the host, because host and insect, unlike host and fungus in many respects, differ fundamentally. With both fungicide and insecticide, however, there must in some circumstances be a possibility of introducing into the edible crop materials toxic to man. For reasons of this kind it is self-evident that progress along these lines is unlikely to come quickly, and must be preceded by long, patient, and often difficult investigations.

(b) Host-resistance to infection

Fruit growers have long been aware that some varieties of apples rarely if ever become Scab infected, even though they are grown alongside susceptible ones. An obvious way to solve the Scab problem commercially is therefore to grow nothing but resistant varieties—obvious, but, as things are, evidently not acceptable, or it would have been done long ago. This situation is by no means confined to apple growing. The best commercial varieties are so often among the most susceptible to disease ; it is not necessary to look further than Cox's Orange Pippin for a first-class illustration. Apple breeding has in the past been carried out by nurserymen mainly with a view to combining good commercial qualities, and disease-resistance was regarded as an acceptable bonus if it happened to turn up. More recently, however, the possibility of combining Scab resistance with good commercial qualities has received attention as a primary scientific aim in plant-breeding programmes at various research centres throughout the world. The raising and prolonged testing of promising new varieties is a tedious process calling for much skill and patience, later to face frustration if resistance is not maintained. It is perhaps less likely that host-resistance will break down than that the Scab fungus will develop more virulence, either through mutations or through gradual selection of the most virulent members of a very varied population. It has been shown with Scab, as with insects, that many types differing widely in virulence can occur as mixtures in the average plantation. Some growers will recall that Bramley's Seedling was at one time listed as a Scab-resistant variety, and, a more recent example, that Conference pear hitherto required much less spraying for Scab than it does now. These are but indications of the gradual shifting of natural biological balance as modified by our need to grow large quantities of healthy crops in concentrated areas.

The device of attempting to increase the Scab resistance of our best commercial varieties has not been overlooked, but research along these lines has hitherto shown only limited promise. The influence of manurial treatments and of grassing-down on the incidence of Scab in the plantation was investigated over a long period at East Malling, and the results were published. It was concluded that even prolonged annual application of normal dressings of nutrients to well-balanced trees was unlikely to have any marked or persistent influence on their susceptibility or resistance to Scab, but treatments sufficiently excessive to react adversely on the nutritional balance of the trees could show clear effects in some circumstances. In general, grassing-down, which reduces the supply of nitrogen immediately available to the trees, tended to reduce the severity of Scab, and as it would tend also to preserve the dead leaves from disintegration and thus increase the quantity of ascospores in spring, the results can be regarded as indicating a likely though at most moderate influence of the sward on tree-resistance.

Indications of the influence of the rootstock on disease resistance in the scion variety, including

Apple Scab and Mildew, were recorded many years ago at East Malling. It is not known how this influence is exerted, but that it should be so is not surprising, for it is well known that the rootstock can greatly influence the tree in other, pomological, respects, which have hitherto been considered of greater commercial importance. But now that increasing attention is being paid to the idea of controlling Scab from within the tree, whether by means of its genetic constitution (resistant varieties) or by introducing fungicides into its system, added importance attaches to any long-term influence of rootstock that can be harnessed to the same end. Research is therefore in progress at East Malling to amplify our information in this respect.

Finally, a noteworthy contribution to the study of host-resistance is to be found in the recent collaborative investigations by members of the East Malling Plant Pathology and Biochemistry staffs. Scab-resistant varieties are not unique in possessing chemical resistance mechanisms in their make-up, for the susceptible Cox's Orange Pippin has them also. Studies in the greenhouse have shown that this resistance, latent in a susceptible variety, can be greatly increased by injecting back into the plant doses of these natural chemicals (inhibitors) that have previously been extracted from its own tissues. Originally contained in the leaves, these chemicals are probably translocated within the plant and could therefore act as systemic fungicides. The investigation demonstrates that resistance and susceptibility depend largely upon the balance between such resistance chemicals and the organic nitrogen present in the tissues liable to attack, and suggests possibilities of adjusting the balance in favour of Scab resistance. Relatively slight changes in the chemical structure of a natural inhibitor such as chlorogenic acid can make a great difference to its performance, so that a whole family, varying each in potency, can be built up in the laboratory. Work is in progress to see whether and how far these investigations can be applied to field practice ; they would appear to have an immediate impact on a survey for systemic fungicides, as well as a bearing on long-term research designed to include the breeding of varieties with a high natural resistance to Scab.

Summary

The annual cycle of the Apple Scab fungus and the requirements for infection are re-stated for fruit growers as the basis of a broad review of past and current research on the various approaches to field control. The merits and limitations of the approach through protective and post-infection spraying are surveyed against the promise of, and the difficulties that beset, an approach through the use of systemic fungicides and host-resistance to infection.

COLLAR ROT OF APPLE TREES

By G. W. F. SEWELL

Collar Rot of apple trees was first diagnosed in England by H. C. Smith in 1953 when he isolated the causal fungus, *Phytophthora cactorum* (Leb. and Cohn.) Schroet., from Cox's Orange Pippin trees in Essex. In 1954 the fungus was found to be responsible for the deaths of trees on the Research Station ; since then *Phytophthora* Collar Rot has been confirmed in orchards in Essex, Kent, Sussex, and Worcestershire. There can be little doubt that the disease is widespread in England but only locally has it become of serious economic importance.

Symptoms

Infection occurs at or near soil level where the bark is invaded. In the early stages the lesion (area of rot) is localized and somewhat irregular in shape (Fig. 1), but it extends rapidly during the warmer months both vertically and laterally, finally girdling and killing the tree. Often there is no external sign of this bark infection at the trunk base and removal of the external corky bark is necessary to reveal the presence of the rot beneath. Occasionally, however, and particularly during the autumn, the presence of such rotting is revealed by a moist appearance of the external bark accompanied by ' sweating ', or vigorous callus growth at the margin of the rotted area may split the corky bark to expose the underlying tissues giving the whole area a striking ' puffy ' appearance.

All bark tissues down to and including the cambium are involved in the rot, but only rarely is the sapwood discoloured. The rotted tissues are dark brown in colour, watersoaked and smell strongly of alcohol. In actively spreading lesions the discoloration becomes progressively lighter towards the margin, passing through brown and orange and merging imperceptibly into the healthy bark. Occasionally, slightly in advance of the margin of the rotted area, small islands of discoloration may occur giving a characteristic mottled effect ; or again a striking ' tiger stripe ' pattern may be produced (Fig. 2). Where lesion margins are not active the diseased area is sharply delimited from the healthy.

Collar Rot in England is primarily a disease of Cox's Orange Pippin ; when worked on M.II or M.IX rootstocks the lower limit of the lesion is usually checked at the graft union. In advanced stages of infection the lesion may extend upwards to involve all bark of the trunk and even of the main branches.

Severely infected trees, which are completely or largely girdled, may blossom and leaf out in the spring and set fruit, but further development is then checked (Fig. 3) ; leaves and fruits remain small and the latter become highly coloured. Later in the season the trees wilt and the branches die. Less severely infected trees may show no leaf symptoms, or symptoms may be confined to certain branches (Fig. 4).

Infection and death of trees may occur in one season or there may be a gradual decline in vigour extending over several years.

Varietal susceptibility

At present Cox's Orange Pippin is the only variety seriously affected in this country. Natural infection of the varieties Ellison's Orange, Lane's Prince Albert, Bramley's Seedling, and Rival have been confirmed by isolation, and typical symptoms have been observed in the field on Arthur Turner and (less commonly) on James Grieve, but attempts to isolate the fungus from these have been unsuccessful. Worcester Pearmain has shown high resistance in inoculation tests.

Of the rootstock varieties, M.II and M.IX show good field resistance (and also in inoculation tests), although infection of both types of rootstock may occur ; each may become extensively invaded from advanced lesions on a susceptible scion variety such as Cox. M.XII, M.XIII, and M.XVI have shown low resistance in inoculation tests, but information concerning their field susceptibility in this country is very limited.

The pathogen

Phytophthora cactorum is soil-borne and semi-aquatic in habit, having a free-swimming motile spore stage and a very resistant resting spore stage ; although conditions of high soil moisture and temperature favour the fungus, it is capable of surviving in soil for long periods under adverse conditions.

Surveys of orchard soils show that the fungus is widely distributed and is not confined to those

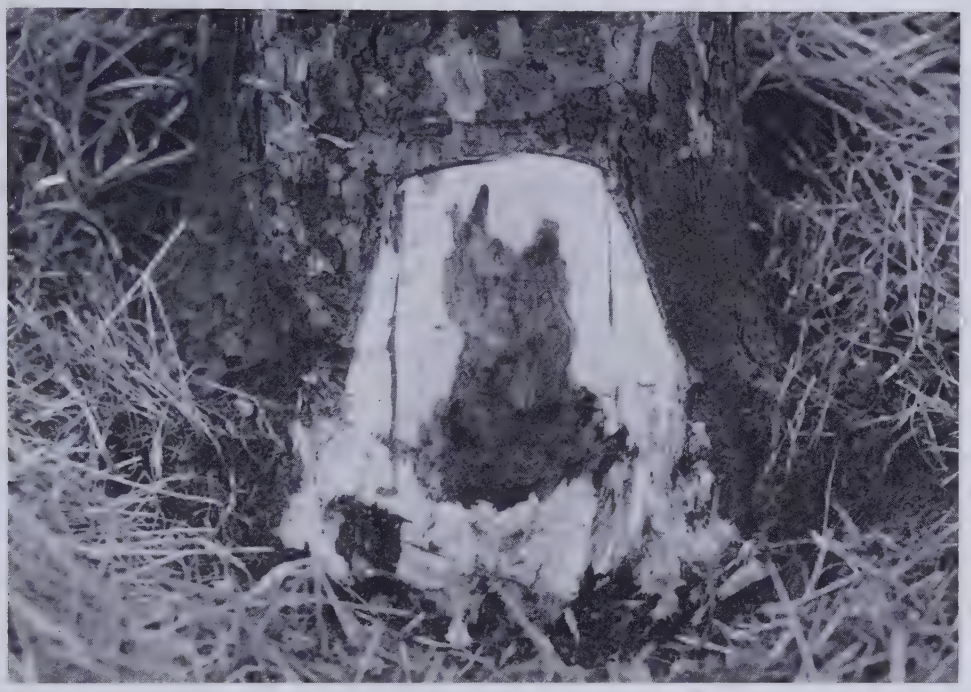

Fig. 1

Early lesions at soil level on Lane's Prince Albert on an unknown rootstock. The external corky bark has been removed

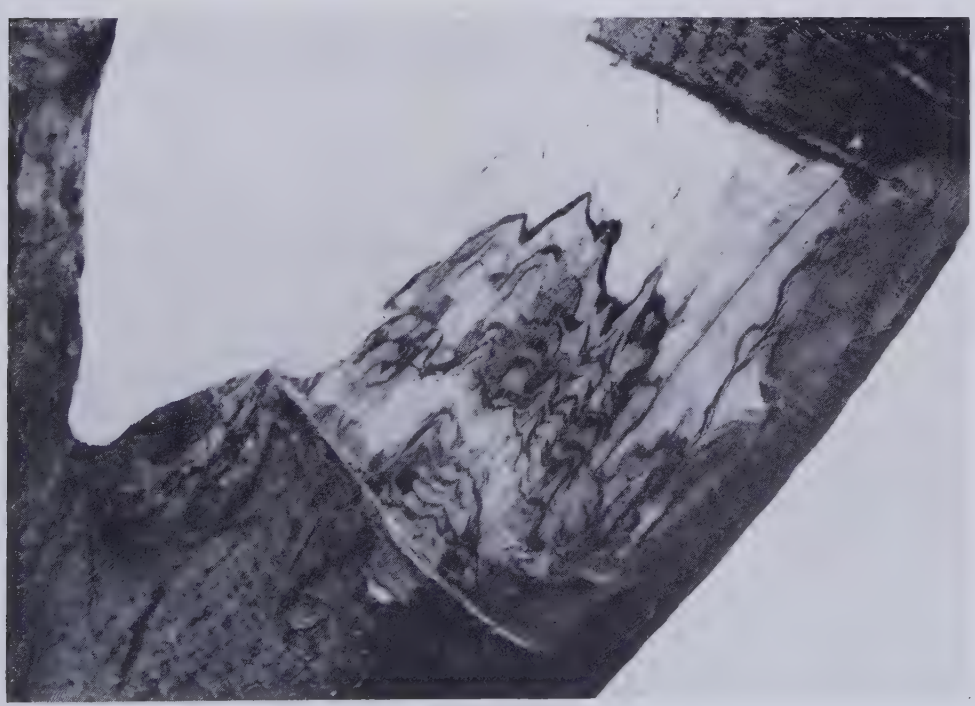

Fig. 2

Lesion margin on Cox's Orange Pippin showing ' tiger stripe ' pattern. The external corky bark has been removed

[face page 168

FIG. 3

Collar Rot of Cox's Orange Pippin, showing sparse and small leaf development in spring following girdling in the previous year

FIG. 4

Collar Rot of Lane's Prince Albert, topworked with Ellison's Orange ; the trunk is half-girdled and one limb wholly girdled

areas of soil around infected trees. The distribution of the fungus in soil suggests that some factor predisposing to infection is necessary, and supports the commonly expressed opinion that bark damage is necessary to permit initial infection. Laboratory tests have shown that *P. cactorum* cannot infect even the susceptible stem tissues of Cox unless the surface bark is damaged.

It is clear from inoculation tests that variation occurs not only in varietal susceptibility but also in the pathogenicity and host range of isolates of the fungus ; it is possible that strains of the fungus capable of attacking the so-called resistant varieties will be encountered.

Control measures

Preventive

1. Graft-unions should be kept above soil level and in particular soil contact with Cox bark should be avoided.
2. New plantings of Cox in infested soil should be made with trees worked high or with an intermediate stock, so that the Cox is well above soil level.
3. Precautions should be taken to prevent trunk injuries particularly at or below soil level.
4. Trunk bases should be kept weed free to prevent the conditions of high humidity which favour the fungus.
5. In infected orchards fallen apple fruits should be removed, as these can become invaded and provide sites for vigorous growth of the fungus.
6. Drainage should be improved where necessary.
7. Trials of various chemicals applied as soil drenches are in progress, but no information of their efficiency is yet available. The application of Bordeaux sprays to the trunk bases and surrounding soil in spring and autumn is recommended by workers in New Zealand and Holland.

Curative

In orchards where Collar Rot has been confirmed, regular inspection of trunk bases for early lesions should be made. All bark lesions should be cut out together with 1 in. of the surrounding healthy tissue and Bordeaux paste applied to the wounds. All diseased tissues should be burnt.

Summary

The symptoms of *Phytophthora* Collar Rot of apple trees are described and suggestions made for controlling the disease. A brief account is given of the susceptibility of the more widely grown apple and rootstock varieties.

TRIALS WITH THE ANTIBIOTIC STREPTOMYCIN FOR THE CONTROL OF BACTERIAL CANKER OF CHERRY

By J. E. CROSSE

Antibiotics are complex substances, produced by certain living organisms, that have the power to inhibit the growth of micro-organisms e.g. fungi, actinomycetes and bacteria, at very low concentrations. The existence of such substances has been known for many years, but it was not until the successful use of penicillin in medicine that they became the subject of major research. Intensive developments during the last decade have resulted in the discovery of many new antibiotics, some of which, e.g. streptomycin, have become well known because of their importance in medicine.

Antibiotics are already being used to promote growth of livestock, and for the preservation of food, and in recent years there has been a growing interest in the possibility of using them for the control of plant diseases. Future developments in this field are likely to be centered on the search for new antibiotics specifically for agricultural purposes. In the meantime, however, considerable exploratory work has already been done with the existing ones, especially with streptomycin.

Streptomycin, like other medical antibiotics, is *antibacterial* and for this reason has been mainly tested against the bacterial plant diseases. As a foliar spray it has given satisfactory control in the U.S.A. of the hitherto intractable Fire-blight of apples at concentrations as low as 0·01 per cent. Similar success has been achieved against Wildfire of tobacco and other diseases and there have been reports of the successful control of seed-borne diseases by soaking seed in streptomycin before sowing. In New Zealand, streptomycin has shown promise against Blast of stone-fruits, a disease which has close affinities with Bacterial Canker of cherry and plum in this country.

Since 1954 field experiments have been in progress at East Malling Research Station to assess the value of streptomycin for the control of Bacterial Canker of cherry. A brief description of these experiments and a discussion of future possibilities follow.

Field trials with streptomycin against Bacterial Canker of cherry (1954-56)

The salient features of this disease have been fully described in a previous article.* Briefly, it will be recalled that there are two phases to the disease, a *summer* phase in the leaves (Leaf Spot) and a *winter* phase in the stems and branches (Canker and Die-back).

We have tested streptomycin against both phases of the disease using:—

1. *Spring* sprays for the control of Leaf Spot.
2. *Autumn* sprays for the control of Canker.

The antibiotic was used as a solution in tap water at low concentrations in the range 0·02 to 0·03 per cent. The actual concentrations used were adjusted, according to the type and purity of the antibiotic sample, to give a certain level of antibacterial activity (in the order of 200 ' international ' units per millilitre).

The sprays incorporated a spreader and were applied at high volume to ' run-off ' using a lance to obtain good cover.

1. Control of Leaf Spot with spring sprays

The trees were sprayed during blossom which we now believe to be the main period for leaf infections. The effects of these sprays on Leaf Spot of Napoleon cherry are summarized in Table I.

TABLE I

EFFECT OF STREPTOMYCIN SPRAYS ON BACTERIAL LEAF SPOT OF NAPOLEON CHERRY

Year	No. of sprays	No. spots/100 leaves		Control (per cent)
		Sprayed	Unsprayed	
1955	3	9	262	96
1956	2	4	39	90

* *Rep. E. Malling Res. Sta. for 1953*, pp. 202-7.

Timing of sprays { 1955 :—full bloom, 75 per cent and 100 per cent petal fall.
1956 :—20 per cent and 90 per cent petal fall.

It will be seen that in 1955 the three antibiotic sprays gave virtually complete control of a very severe outbreak of Leaf Spot, while in 1956, two sprays gave excellent control of a less severe attack. We have not yet tested the effect of a single application during blossom, but we expect that this would give some control, although less than with 2 or 3 sprays. Results similar to those on Napoleon were also obtained on the more resistant variety Roundel.

2. Control of Canker infections with autumn sprays

Sprays were applied in September and October and the effects of these on Canker infections recorded in May or June of the following year. Most infections occurred on the branches, and the figures in Table II refer to the total numbers of these, irrespective of severity.

TABLE II

EFFECT OF STREPTOMYCIN ON CANKER INFECTIONS OF NAPOLEON CHERRY

Year	No. of sprays	Average No. of infections per tree		Control (per cent)
		Sprayed	Unsprayed	
1954	2	5·4	19·6	72
1955	2	4·7	15·0	69

Timing of sprays { 1954 :—both in the last week of September.
1955 :—in the first week of September and first week of October respectively.

In both years control was fairly good, but less spectacular than that obtained with the spring sprays against Leaf Spot. In 1955 there were some indications that streptomycin had been less effective against the more serious forms of the disease, i.e. those causing cankering and die-back of branches, than against the milder forms involving only the fruiting spurs. It remains to be seen in future experiments whether this tendency is maintained.

Phytotoxicity of streptomycin

It is known that streptomycin may be injurious to plants, but we have never observed any adverse effects in our experiments, either on blossom set, growth or on leaf colour. The most characteristic form of streptomycin injury is a chlorosis of the young leaves, and this may follow application of the antibiotic at quite low concentrations. In one instance, for example, marginal chlorosis of apple leaves was observed in the U.S.A. after four blossom applications of streptomycin at concentrations lower than those used in our experiments.

Tests on greenhouse plants at East Malling have shown cherry to be susceptible to this type of damage. Thus the question of increasing antibiotic concentrations in the field sprays, particularly those applied to the immature leaves in the spring, will have to be approached with caution. The leaf chlorosis is now believed to be due to some effect of the antibiotic on chlorophyll synthesis.

How does streptomycin compare with conventional spray materials?

The complete answer to this must await the results of current trials in which streptomycin is being directly compared with more conventional bactericides. In the meantime comparison of the present results with those of previous trials with *freshly made* Bordeaux mixture, the best of the conventional bactericides, suggests the following:—

1. As a spring spray streptomycin was superior to Bordeaux mixture for the control of Leaf Spot. This may be partly due to the fact that streptomycin was applied during blossom, whereas the use of Bordeaux mixture has hitherto been restricted to the pre- or post-blossom stages because of the danger of spray damage.

2. As an autumn spray streptomycin was slightly better than Bordeaux mixture. There is now evidence, however, that the control with Bordeaux mixture may be improved if the timing of the sprays, at present recommended for the end of September and again a few weeks later, be advanced. If this is confirmed then streptomycin might become relatively less effective.

As far as actual spraying is concerned streptomycin has clear advantages. The sprays are easy to prepare and no more difficult to apply than water, except that care must be taken to avoid contact

of the spray with the skin. Apparently there may be a risk of this causing hypersensitivity to the antibiotic in some people which would then make it difficult to treat them with it, if this ever became necessary for medical reasons. With the low antibiotic concentrations likely to be used in plant protection the risk may not be very great, but in the present state of our knowledge we cannot afford to ignore it.

Could the control with streptomycin be improved?

The degree of control could almost certainly be improved by increasing the concentration of the antibiotic in the sprays, but the danger of phytotoxicity and prohibitive costs would soon restrict this.

There may be other ways of improving control, however, when we know more about the mode of action of streptomycin.

The conventional bactericides, e.g. Bordeaux mixture, act on the surface of the plant and their effect is to destroy the bacteria before they invade the leaves, stems, or branches. We know that streptomycin has a tendency to become systemic in plants. It is possible, therefore, that the control of cherry canker was partly due to some effect of the antibiotic on the growth of the bacterium *inside* the plant. Activity of this kind has already been demonstrated in Halo Blight, a bacterial disease of dwarf bean. We are investigating the possibility of systemic activity in cherry and if this is found to occur it may well be possible to improve control with formulations assisting the penetration of the antibiotic into leaves and other parts of the tree. An advantage of systemic activity would be to reduce the importance of obtaining good coverage with the sprays, since redistribution of the antibiotic would occur within the plant. We might then expect streptomycin to be relatively more efficient than conventional bactericides in cases where adequate cover was difficult to obtain, as for example on large orchard trees.

Future prospects

For various reasons it is too early to forecast the commercial future of streptomycin. Even if streptomycin eventually proved superior to other materials for disease control, there are still other problems to be considered. Firstly, there is the question of cost. Antibiotics are relatively expensive to produce and although improvements in manufacture have made it possible to consider them as relatively low-priced plant protectants, the extent to which they will compete with conventional materials is still not clear. Another problem arises from the medical uses of streptomycin. It is very important in the treatment of tuberculosis and this function might be prejudiced by indiscriminate dosing such as could inadvertently occur, for example, from residues in or on the crop. This problem is particularly important because of the possibility of systemic activity in plants treated with the antibiotic. There is nothing yet to suggest that streptomycin might accumulate in cherry fruits, but obviously the whole question will have to be carefully considered, especially in relation to cropping trees.

The use of medical antibiotics in this country is restricted by law, but precedents exist for allowing their use in agriculture as for example in the addition of antibiotics to animal feeding stuffs. In the U.S.A. antibiotics are permitted as plant protectants so long as certain health requirements are fulfilled and commercial formulations are already being marketed at prices that are presumably competitive with those of conventional materials. There is one final problem that may have to be faced before antibiotics become fully established in agricultural practice, namely the tendency for bacteria to develop strains resistant to antibiotics. This is already a matter of concern in medicine, and there seems no reason why it should not also occur amongst bacteria attacking plants. So far there is no evidence of this from the field, but it has been clearly shown under test tube conditions that certain plant pathogenic bacteria can be ' educated ' to withstand abnormally high antibiotic concentrations.

However, forewarned by medical experience, there seems to be a general confidence that this problem could be overcome if it ever arose.

Summary

Field trials with streptomycin against the Leaf Spot and Canker stages of Bacterial Canker of cherry are described and the possibilities of the antibiotic for the commercial control of the disease discussed.

MORE ECONOMICAL STRAWBERRY PLANTING*

By W. S. ROGERS

The value of planting only the healthiest strawberry runners is now undoubted ; and the surest way to keep the highest standard is to plant certified Special Stock virus-free plants. But such plants are expensive to produce, and so are fairly costly to buy. It is therefore worth considering any planting system that requires fewer plants per acre than usual. Several different planting systems have been tested at East Malling, and are described in two research reports, from which the practical points are discussed below.

The spaced row

The commonly used spaced row system, with plants at 36 in. × 18 in. requires 9,680 plants per acre. This spacing has given good yields at East Malling, and has provided the standard of comparison in all our trials. Weed control by mechanical and hand hoeing is fairly simple, and runners are removed as they form.

The hill system

This system, involving planting at 36 in. square, uses half as many plants as the spaced row. Mechanical cultivation can be maintained in both directions, and hand hoeing is minimized, so there is a good saving in labour costs. But in our trials the yield per acre was 38 per cent less than that of the spaced row—a loss that is unlikely to be offset by the saving in planting and labour costs.

Matted rows

One possible economy, that we tested quite early, was to allow the runners that grew in the first season to form a matted row, about 18 in. wide. In this way the runners were changed from a liability, costing money to cut off, into an asset. Such matted rows gave yields over 40 per cent higher than comparable spaced rows. The increase comes from the large number of fruiting crowns provided by the ' self planted ' mat of runners ; for we found in our first trials that, within limits, high yield depended largely on the number of fruiting crowns per acre.

The extension of this method to form 36 in. matted *beds*, by allowing runners to fill alternate alleys, was not so satisfactory, however. Such wide beds proved hard to pick and to keep clean ; and the beds suffered severely from drought in some years. Narrower matted beds, 24 in. wide with 24 in. alleys, were also generally no better than matted rows, and less easy to manage.

The new hill-mat system

We have been testing for the last five years a new ' modified matted row ' system which offers some of the advantages of both the hill and the matted row. For brevity I will call it the hill-mat system. It consists simply of planting at 36 in. square (4,840 plants per acre), cultivating both ways until runners are ready to root in June or July of the first season, and then laying the runners to form matted rows 18 in. wide. We have found that the parent plants at 36 in. produce sufficient runners to form a good matted row (Fig. 1) and that such matted rows yield just as well as ones formed from twice the number of parents. In this way, planting costs can be almost halved, with no loss of final yield.

It might be thought that earliness and size of fruit would suffer, in the matted row, but in fact this has not been so. This is probably because, in the second year (the first main cropping year) many of the plants in a matted row are maiden plants, which produce early and large fruit. In years of bad *Botrytis* rot attack, a rather higher proportion of fruits have suffered in the matted rows ; but even so, the yield of marketable fruit has still been higher than that from spaced rows. In very dry years, matted rows also suffer more from drought than spaced rows ; but over ten years matted rows have given considerably higher crops than spaced rows.

Factors for success

To ensure success with the hill-mat system, careful attention must be given to several practical points. Since the original plants are widely spaced, losses from wireworms, rabbits, or frost lifting must be carefully guarded against or made good by gapping up. The land must be free of weeds at

* Reprinted, with minor amendments, from *The Grower*, **46**, 766-7 (1956).

the time of laying-in the runners and the runners must be laid in place before they begin to root, so that they quickly form a mat which will stifle new weed growth. Cultivating each alley always in one direction, from this time onwards, will help to keep the runners in place (Fig. 2).

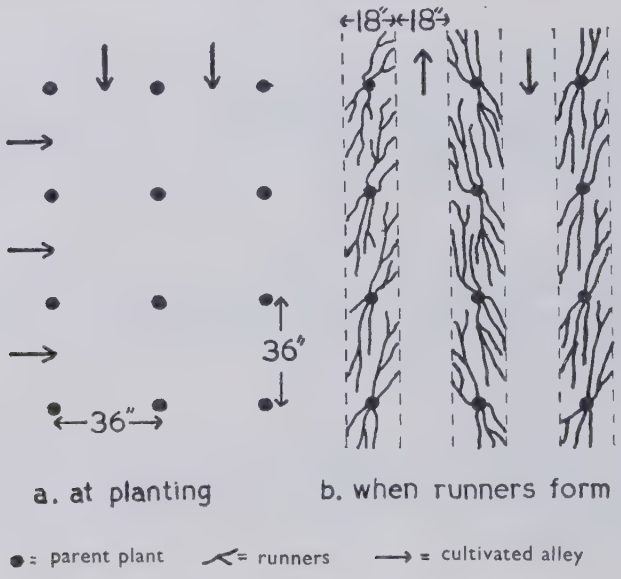

FIG. 2

Arrangement of plants and cultivated alleys in the hill-mat system.
(*a*) at planting. (*b*) when runners form

Should we deblossom?

All our spacing trials were deblossomed in the first season ; but this practice is probably less important for matted rows than for spaced rows. The effects of deblossoming are to invigorate the original plants and to increase early runner production. In the matted systems the crop depends mainly on the runners, and there are usually plenty of runners to form a mat, whether the parents are deblossomed or not. If the original plants are allowed to fruit as maidens, however, care must be taken to clean the ground in good time for the runners to root.

The maiden crop per acre from the original plants in the hill-mat system would of course be relatively small, because of their wide spacing. Where much importance is attached to the maiden crop, because of its earliness and quality, the old closer planting systems still have great advantages. Where low planting cost and high final yield are the main consideration, the hill-mat system has great economic advantages.

Large-scale tests

The hill-mat system as here described is, as far as we know, a new development ; and it obviously needs testing on growers' farms before it can be generally recommended. The method has been tested by three growers, on areas of several acres with Royal Sovereign, Climax and Talisman, and they have reported successful results (cropping data for Talisman will not be available until 1957).

The planting distance can, of course, be modified, within limits, to suit available machinery and differences in growing conditions ; but a cultivated strip 18 in. wide is about the minimum that provides good access for picking.

Acknowledgements

I should like to acknowledge the help and collaboration of Miss D. J. Wilson in the recent trials.

Summary

The new hill-mat planting system, developed at East Malling, offers great savings in costs of planting and early cultivation. The method still needs proving in different areas.

Fig. 1

Two rows of Royal Sovereign in the 'hill-mat' system, on 4th September, 1956. The runners have already filled the spaces between the original parents at 36 in. in the row. Ordinary matted rows from parents at 18 in. are seen in the corner

[face page 174

PREDACIOUS SPIDERS AND MITES ON FRUIT TREES

By D. A. CHANT*

Many of the insecticides that efficiently control orchard pests have led, in certain cases, to an increase of other plant feeding insects and mites in the orchards where they have been applied. Much interest has, therefore, been shown in studying other methods, especially biological control—that is, the use of insects and other organisms that limit the pest species. In England, the life histories and habits of many beneficial species have been investigated, particularly at East Malling, but two groups that have been neglected are the true spiders (Araneae) and the predacious mites of the sub family Phytoseiinae. For the past three years the author has been studying these two groups at East Malling and this paper is a brief report of the results of this investigation.

True spiders

Spiders are ubiquitous and more than 30 species have been recorded in apple orchards in Kent and Essex. Because all spiders are predacious, it was important to assess the value of this large number of species as controlling agents of common orchard-inhabiting pests.

Spiders can be distinguished from insects and other allied groups by the possession of eight legs and a distinct division of the body into two parts known as cephalothorax and abdomen. Insects possess but six legs and true mites show no distinction between the various parts of their bodies. Spiders, of course, are extremely common, but only those families that are abundant in orchards are of interest in the present context ; in England, there are only three of these, Argiopidae, Theridiidae, and Linyphiidae. The former are large when mature with a body shape as shown in Fig. 1. They rarely attain high densities, but being large in size their feeding capacity can be great. Theridiids are smaller spiders of about $\frac{1}{4}$ in. length, with large abdomens usually patterned in black and white. Linyphiids also are smaller spiders, but their abdomens usually are a uniform shining black.

Argiopids spin large symmetrical webs which are noticeable on fruit trees, particularly after a dew has fallen. Frequently a web will appear empty and derelict, but a careful search will discover the occupant hidden in some nearby retreat ; a guide line of silk connected to the webbing serves to register the capture of prey. Because this method of capture is used, flying insects of many sorts form the bulk of the food supply of these spiders. Orchard-inhabiting Argiopids probably pass through but one generation per year.

Theridiids spin no formal type of web, merely trailing a single thread of silk. When a spider has roamed a single leaf or spur to any extent, a very untidy webbing is formed from this trailing guide line. Theridiids often search for their prey and therefore small crawling insects form a larger part of their diet than do flying insects, although the latter may be caught on occasion in the crude webs. Theridiids generally pass through one or two generations per year and in unsprayed orchards sometimes attain very large numbers. They chiefly inhabit the leafy parts of fruit trees and are rarely found on bark during the summer. They hibernate as immature or adult individuals.

Linyphiids also spin no formal webs, although they may achieve a clutter of silk at the junction of two twigs or in similar places. The species occurring on apple trees appear almost entirely to search out their prey and therefore flying insects form but a small part of their diet. These also appear to possess one or two generations per year and in unsprayed orchards may attain large numbers. They prefer the woody parts of the fruit trees and are not usually found on the leaves. This group of spiders seems to prefer orchards in shady, damp locations, while Theridiids are often more common where there is sunlight and warmth.

These three families of spiders were studied to determine which of the insects occurring in orchards they will accept as food. Argiopids were found to prefer larger insects such as winter moth larvae and adults, codling moths, aphids, and predacious insects such as the Black-kneed Capsid and other mirids. Only when very young would they feed on the Fruit Tree Red Spider Mite, but this is uncommon in nature because the mites rarely become entangled in the webs of this group and the spiders rarely move away from their webs in search of food.

Linyphiids and Theridiids both will live apparently normally when provided with nothing but the red spider mite as food. When such food is scarce these spiders will eat only a few each day, although they will continue to live and develop normally. However, under conditions of high prey density they will consume as many as 10 mites per day, thus when prey increase in number, the

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mortality these predators inflict also increases. This is necessary if a predator is satisfactorily to control a pest species.

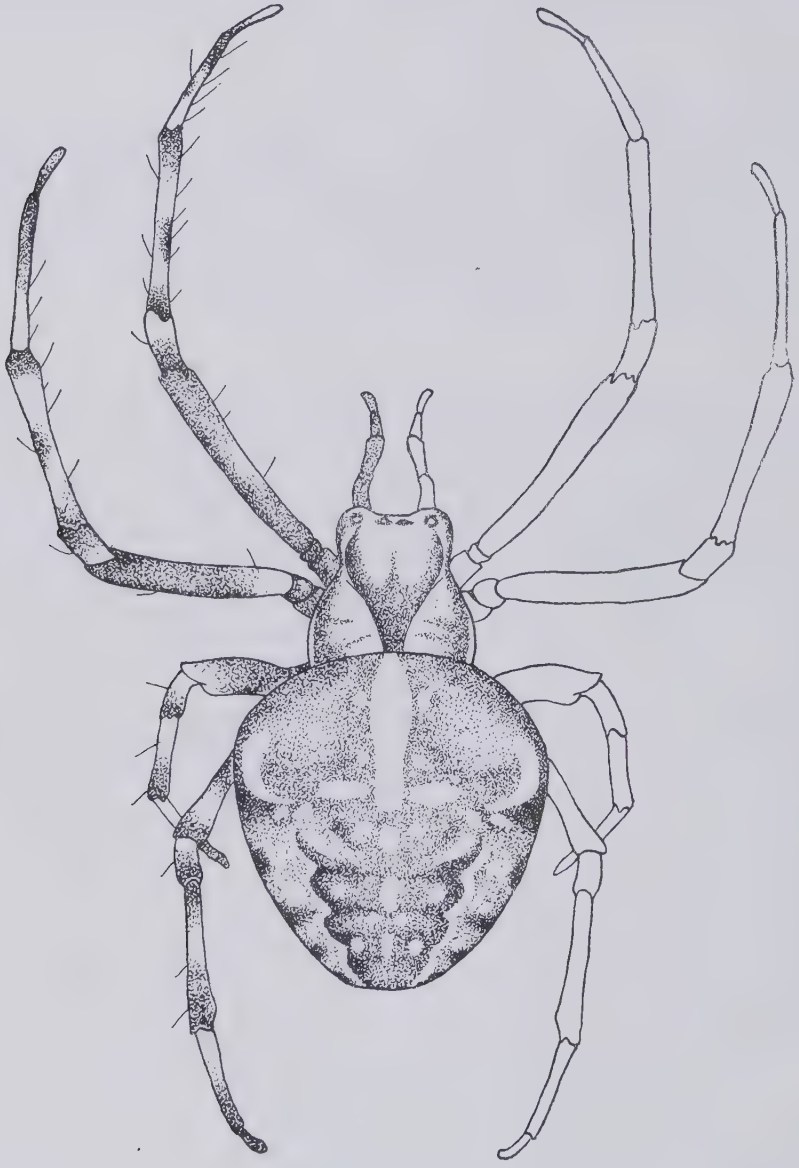


FIG. 1
Typical spider of the family Argiopidae

However, in nature, mites are not their only source of food ; they feed readily on small aphids, and also on immature predacious insects. It has not been determined which type of food they *prefer* when an abundance of all types is present ; it may be that alternative sources of food are always utilized in nature with the result that the effectiveness of the spiders as natural enemies of the Fruit Tree Red Spider Mite is dissipated. This also is true of Argiopids, and it may well be that spiders in general are not sufficiently specific in their feeding habits to justify any attempt to utilize them as beneficial insects in orchards. Much work remains to be done.

All sprays were found to be detrimental to spider life. Some sprays perhaps are not actually toxic to the spiders, but nearly all applications remove the spiders by jarring them from branches and leaves, the result being the same as if they were killed by chemical action. For this reason, as with most beneficial insects, spiders are much more abundant in unsprayed orchards, and in well-kept

orchards they rarely appear in large numbers until late in any season, usually when it is too late to effect any major control of a pest species.

Predacious mites

Most fruit growers are familiar with this group even though they may never have seen specimens. These are extremely small, colourless mites of the subfamily Phytoseiinae. They are found on nearly every type of plant in south-eastern England and 16 species have been recorded in Kent and Essex. However, only 9 species are found on unsprayed fruit trees, and of these only one, *Typhlodromus tiliae* Oudemans, can tolerate conditions in sprayed orchards.

These mites pass through three or four generations per year (compared with five for the Fruit Tree Red Spider Mite) and rarely seem to achieve large densities on fruit trees. The females are not prolific, laying perhaps only 10 eggs during their adult lives. The immature mites require about three weeks to mature from hatching and during that time pass through three stages—larva, protonymph, and deutonymph. They overwinter only as adult females, under bark and in deep crevices on the host tree. Winter mortality in Kent is severe and usually destroys more than 90 per cent of the mites. In summer, they are preyed upon by many of the same predacious insects that attack the red spider mite and in some instances mortality from this cause may be severe.

These mites inhabit the undersides of leaves and rarely are found on the upper surfaces. Also, they are most abundant on younger leaves of the trees throughout the season. The Fruit Tree Red Spider Mite, on the other hand, frequently is found on the upper surfaces of leaves and it has been estimated that as many as 30 per cent of the population sometimes is to be found here. The red spider mite prefers the older leaves of apple trees early in the season and it is not until mid-summer when large numbers may have developed that the red spider mite completely ' invades ' the territory on the trees where the majority of the predacious mites are to be found.

The feeding habits of predacious mites were investigated both in the laboratory and under field conditions. It was found that they are by no means completely predacious, and that adult mites can live for a long time with no food other than apple leaves. The young, however, cannot develop on this diet and some source of protein is necessary. This need not be animal ; pollen grains and fungal spores both provide food permitting the immature mites to develop normally, and the females to lay eggs. In addition to these foods, a variety of mites also may be consumed ; they are cannibalistic and also feed on all species of mites found on fruit trees. When feeding upon extremely small mites such as the Apple Rust Mite, *Vasates schlechtendali* (Nal.) or the Plum Rust Mite, *Vasates fockeui* (Nal. & Trt.), development takes place in approximately half the time required when their food consists of larger mites such as the red spider mite. The consumption of these small mites may be as high as 90 per day, but typhlodromids rarely consume more than 2 or 3 red spider mites per day, and the egg stages of the latter are virtually immune from attack. This variety of food means that typhlodromids are not dependent on any one prey species, with the result that they do not necessarily increase in numbers when the prey increases.

It was necessary to determine to what extent these other foods are utilized in the field when there is an abundance of red spider mites. It was found that there is a convenient index that can be used in this connexion ; when a typhlodromid mite feeds upon the red spider mite, its intestine turns a reddish colour and this remains in most individuals for three days. Therefore, if a predacious mite with a colourless intestine is collected in an orchard where red spider mite is abundant, one may conclude that this predator has not fed upon the red spider mite for at least three days, and that it must be utilizing the other sources of food.

This was investigated in an orchard on East Malling Research Station where the numbers of red spider increased to 300 per leaf in 1955. Regular collections showed that not more than 50 per cent of the typhlodromid population at any one time possessed reddish intestines, and it may be concluded that not more than this percentage had recently fed upon the red spider mite. Therefore, the alternative source of food must be utilized to a considerable extent even in the presence of abundant red spider, with the result that the effectiveness of the predator is largely dissipated.

To test the validity of these conclusions under field conditions, the predacious mites were removed from some young apple trees by hand, thus ensuring that there were no subtle and incompletely understood chemical side-effects resulting from the use of sprays ; no sprays were used except one uniformly applied for the control of other pests. Over a period of two years it was observed that the density of red spider mite was not affected by that of the predacious mites ; on the trees where the predator was abundant there were no fewer red spider mites than on the trees where the predator was absent. Thus, the predator had no apparent effect on the pest.

It therefore may be concluded that this species is not uniformly effective against the red spider mite, and, indeed, that it possesses many characteristics that may render it ineffective under almost all conditions. This also is the case with true spiders and the author feels that before these predators

are hailed as species of great potential value in orchard economy, exact quantitative studies are necessary to determine the true status of their effectiveness.

Summary

Brief descriptions of the true spiders and predacious mites that inhabit orchards are given, together with notes on their life histories and feeding habits, and their probable importance as predators of orchard pests.

THE DEVELOPMENT OF CHROMATOGRAPHY*

By A. E. FLOOD

Since the time when chemists first became interested in substances occurring in living organisms, an important barrier to further progress has been the difficulty of separating individuals of any group of compounds similar in chemical properties. This was true of the members of such important groups as sugars and amino acids, and defied solution until nearly halfway through the twentieth century. Many substances of considerable importance in nature occur in small quantities, so to the demand for a method of separation was added the need to work on a very small scale. The alternative was to start with enormous quantities of material in order to obtain sufficient of the compounds sought. This is unsatisfactory both from the point of view of time and expense, and, of course, in many cases large quantities of starting material are not available.

The key to the solution of the problem must be sought among physical methods ; chemical methods are unlikely to be helpful since the compounds to be separated are of similar chemical properties. A valuable attempt to treat such a problem had been made by the Russian botanist Tswett in 1906. He was interested in the pigments of green leaves. It was known that if a solution of these pigments in petroleum ether were shaken with calcium carbonate powder, some of the pigments were adsorbed on the powder and some were not. Tswett made an important modification to this procedure by packing the powder into a vertical glass tube and pouring the solution of pigments on to the top of the column. As the solution percolated through the carbonate, the pigments were seen near the top and when all the solution had passed in, Tswett washed the column with pure solvent, i.e. petroleum ether. He found that the pigments began to separate into bands on the column whilst a yellow pigment (carotene) washed right through. After some time the bands of each pigment became well separated with colourless zones in between. The column could now be drained, extruded from the containing glass tube and the zones or bands of pigments cut out with a knife. Each segment of carbonate containing an adsorbed individual pigment was extracted with alcohol and Tswett now had in alcoholic solutions the single pigments of his original mixture. He called the column with its various bands of pigments a chromatogram and the whole process chromatography (from the Greek ' chroma ' meaning colour). Although nowadays the procedure has been extended to the separation of colourless substances the original terms are still retained.

Tswett's work lay virtually unnoticed for nearly twenty-five years. Early in the nineteen thirties it was successfully used for the separation of pigments closely related to carotene. Since then it has been used more and more until today it occupies an important position both as a preparative and analytical tool. The method depends on differences in adsorption of substances on a solid (called the adsorbent) in the presence of a solvent. Thus, of the two phases present, one is solid and one is liquid. In 1941 Martin and Synge described a rather different type of chromatography where the two phases present are both liquid ; they called it partition chromatography as opposed to adsorption chromatography described above. In the field of plant biochemistry it is this type of chromatography which has contributed greatly to the solution of the problem posed at the beginning of this article.

The physical characteristic used as a basis for the separations achieved in partition chromatography is the ' partition coefficient '. This measures the way in which a single substance will be distributed between two different solvents when present together, i.e. the substance has equal access to both solvents. It may dissolve more readily in one solvent rather than the other and when both are at hand there will be more of the substance in the solvent that dissolves it the better. The idea of a partition coefficient goes back to 1872 when Berthelot and Jungfleisch found that if iodine were added in varying amounts to a mixture of carbon disulphide and water, then the iodine distributed itself between the two solvents (or phases as they are called) in such a way that at a given temperature the ratio of the concentration of iodine in each phase was a constant.

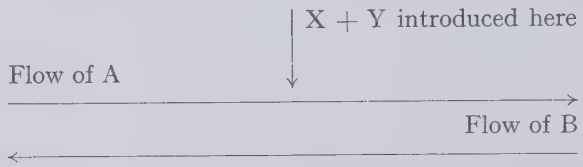
$$\frac{\text{Concentration of iodine in carbon disulphide}}{\text{Concentration of iodine in water}} = \frac{C_1}{C_2} = K$$

This constant K is called the partition coefficient. It was known that the individual members of such groups of compounds as sugars and amino acids did differ in their partition coefficients, although these differences were small. If some method could be devised capable of exploiting these small differences, then a separation might be achieved. Partition chromatography fulfils this purpose.

In its original form it consisted of each of two solvents flowing through a series of vessels, but in

* Reprinted by permission, with minor changes, from *Scientific Horticulture*, **12**, 110-17.

opposite directions, hence the name ' countercurrent ' given to this partition method. The mixture to be separated is introduced into the middle of the system. Consider the simple case of the separation of a mixture of two substances X and Y using two solvents A and B, and that we have chosen A and B because we know that X is more soluble in A than in B (i.e. its partition coefficient is more in favour of A than B) and that the reverse holds for Y. The system may be represented by a diagram as follows :



After the system has been running for a while we would expect to find that X has tended to travel in the direction of flow of solvent A (since it is more soluble in this solvent than in B) and Y in the direction of flow of solvent B. In other words we would have a predominance of substance X to the right of the diagram and a predominance of Y to the left. This is called a process of enrichment, and if we made the system big enough, eventually we ought to get all X and no Y to the right and all Y and no X to the left. We should have achieved a complete separation of X and Y, making use of their different partition coefficients with respect to A and B, solvents we have carefully chosen with this particular aim in view.

Large pieces of apparatus capable of doing this sort of work have been constructed, but there are certain practical difficulties associated with countercurrent separations. One of these s that of making sure that the two phases (solvents) do in fact move in the direction intended. Sometimes they get caught up with each other and some of each solvent then moves in the opposite direction to that wanted—a nuisance known as entrainment which leads to inefficient separations.

With this difficulty in mind, Martin and Synge turned towards the idea of making one phase stationary. There would then be only one flowing phase and difficulties due to entrainment avoided. The phase they chose to fix was water, the solvent pair used being a mixture of an organic solvent such as chloroform, and water. Their first method for keeping the water phase stationary was to absorb it on silica. A suitable preparation of silica will absorb up to 70 per cent by weight of water and still exist as a ' dry ' powder. This silica gel can be packed into a glass tube just as easily as Tswett, many years before, had packed his calcium carbonate. It is usually done by stirring the gel into the organic solvent and pouring the resulting slurry into the tube. The latter is rounded and fitted with a tap at the bottom end with some form of filter pad just above the tap, and as the solvent from the slurry flows out of the tube the gel settles down as a nice even pack. The column is never allowed to run dry, a small depth of solvent being always kept covering the top. The mixture of substances to be separated is dissolved in the minimum quantity of the organic solvent and the solution added to the top of the column. The tap is opened and the solution allowed to drain just into the silica gel, and then the organic solvent fed in continuously from the top of the tube. Bands are formed on the column and eventually pass out through the tap, each individual band as it emerges being collected in a separate container (Fig. 1). Removal of the solvent from each fraction collected leads to the isolation of the pure components of the original mixture. The collection of each band as it passes out of the column is a technique generally used in preference to extrusion of the column as described earlier.

Although this form of chromatography is similar in technique to adsorption chromatography, the two must not be confused as they are based on different principles. The point to grasp is that in partition chromatography the solid used as packing in the column serves only as an inert support for a static water phase. It is a device for holding a column of water stationary in the tube so that an organic solvent is the only moving liquid (or phase). The solid support plays no part in the chromatographic process.*

If the simple principles developed so far are remembered there should be no difficulty in following the next type of partition chromatography to be described. It is probably the one most frequently used and forms an everyday tool in all biochemical laboratories. No special equipment is required and the technique is simple and elegant. Moreover, it will deal with minute amounts of material, which, as we noted earlier, is a requisite of prime importance. The name, too, is simple—paper chromatography, and it may be regarded as an alternative to the method just described, the principles being the same.

In 1944 Martin and his colleagues tried replacing the silica used for supporting the static water

* It is now known that this is not strictly true, but the part played by the support is a modifying one and may be ignored in an elementary discussion, thus avoiding confusion.

phase by another type of material with a high affinity for water, viz. filter paper. Filter paper takes up water quite readily without becoming wet in the ordinary sense of the word (think how blotting paper soaks up ink). With paper as the water support the whole process is now quite simple. A strip of filter paper is taken and a pencil line drawn across it near one end. This is called the starting line. The mixture to be separated is dissolved in any suitable solvent and a tiny drop of this solution transferred to a point on the starting line. The drop should contain 30–40 millionths of a gramme of each component of the mixture. The small spot arising from this drop is allowed to dry and the paper is now ready. It must be realized that the solvent used for dissolving the mixture plays no part in the chromatography. It is merely a vehicle for transferring a tiny amount of the mixture to the paper and having served this purpose it is removed by evaporation when the spot dries.

Meanwhile the organic solvent chosen for use in the separation is shaken with water. The organic solvent is often an alcohol partially miscible with water.* Two phases are formed, one rich in water and one rich in alcohol. The water rich phase is placed in the bottom of an airtight glass tank and the alcohol rich phase reserved for subsequent use. The purpose of this procedure is to ensure that during the running of the chromatogram the vapours in the tank will be in equilibrium with respect to the water and the alcohol. The paper is now hung in the tank over a glass rod stretched across the tank near the top and with the end of the paper near the starting line dipping into an empty trough supported parallel to the glass rod. A well-fitting lid is put on the tank and the assembly left for a few hours (Fig. 2).

During this time the paper picks up water from the vapour in the tank and eventually hangs quite limply. We now have what amounts to a static sheet of water supported by the paper with the mixture to be separated embedded in it at the starting line. A small hole in the lid is uncovered and the trough filled with the alcohol rich phase, the hole then being quickly covered again. The alcohol now flows slowly down the paper, the time taken varying with the solvent, temperature, type, and length of paper and may be anything up to 18 hours, although longer times are often used. The progress of the flowing solvent may be watched, since it appears to render the paper slightly translucent.

When the solvent front has reached nearly to the end of the paper, the latter is removed from the tank, the position of the solvent front marked, and it is then dried in a current of air. If the conditions of the experiment have been chosen correctly, the components of the mixture will appear as discrete spots spaced out along the paper strip just as in the previous method the individuals of the mixture were spaced out as bands along the column.

A component that shows a preference for the alcoholic phase, i.e. one that has a partition coefficient in favour of that phase, will tend to travel with it becoming separated from one which because of its preference for the water phase remains close to the starting line where it was originally deposited when the mixture was applied to the paper. This method of running paper chromatograms is known as ' descending '. Ascending methods are also available.

It was pointed out earlier that chromatography was so named because it was used for separating coloured substances. Later it was used for colourless compounds and these now form the majority of substances studied. Therefore it usually happens that when the paper strip is removed from the tank and dried it appears as a blank piece of paper. The next stage is concerned with revealing the presence on the paper of compounds (spots) that have been separated. Here many simple methods are available. It is fortunate that one group of compounds important in plant biochemistry will fluoresce or emit colours when viewed in ultraviolet light. The coloured spots are outlined in pencil because they become invisible again when the ultraviolet source is removed. Alternatively, the paper may be sprayed with a solution of any reagent that will give a coloured product or even a stain on the paper with the substances being sought. An example that immediately springs to mind is the use of an indicator solution (e.g. litmus) when acids are being separated. Litmus turns red in the presence of acids and will produce red spots on the paper where the acid spots occur. If the reaction needs heat to be effective the paper after spraying may be hung in a hot oven when the coloured spots appear after a few minutes.

In the study of radioactive tracers the spots may be detected by scanning the paper with a counter or by leaving the paper in contact with an X-ray photographic plate. Subsequent development of the plate reveals black areas which correspond to the position of radioactive spots on the paper. With antibiotics the paper is often laid over a dish of agar jelly inoculated with the organism being studied. After the necessary period of incubation the position of antibiotic spots on the paper is revealed by corresponding areas of inhibited growth of the micro-organism on the agar. These examples by no means exhaust the possible methods that can be used. An interesting method has been described recently by some Japanese workers. They were dealing with a substance which is a sex attractant

* Much more complicated solvent mixtures are often used, some of which are miscible with water, but they need not concern us here.

discharged by the female silk worm moth, *Bombix mori*, and they separated this compound on a paper chromatogram. After drying the paper it was (to quote the authors) ' passed slowly in front of the male moth. When the spot of the sex attractant approached the male, the insect became excited and went round the spot shaking his wings violently '.

We have now reached the stage when the chromatogram has been run and the position of the separated components revealed. One final stage remains to be described. This is concerned with the identification of each separated spot. If for example, a mixture of two sugars A and B are separated on the paper giving two spots, how do we know which spot is due to sugar A and which due to sugar B? One way of doing this is based on the fact that under standard conditions the distance a substance travels from the starting line is a characteristic of that particular substance. This is conveniently expressed by a ratio obtained by dividing the distance of travel of the compound by the distance travelled by the solvent. This ratio is called the R_F value.

Thus,

$$\frac{\text{Distance travelled from start by substance A}}{\text{Distance travelled from start by solvent}} = R_F \text{ of substance A}$$

Under the same standard conditions substance A will always have the same R_F value. Chromatograms of all the known sugars can be run and a table of R_F values compiled. This provides a chart for allocating a name to each spot of the pattern obtained on the paper when a sugar mixture is separated. Other groups of compounds can be treated similarly.

Because of the care necessary to run chromatograms under strictly standard conditions it is often more convenient to run on the same sheet of paper beside the mixture being separated, a series of spots of known compounds. These serve as markers, and since they are chromatographed at the same time as the mixture, their distances of travel are directly comparable with spots arising from the mixture (Fig. 3).

The question often arises as to the identification of a new compound for which no R_F value has ever been recorded. This entails an interesting piece of detective work. The chromatographic behaviour of the compound must be considered in the light of evidence gleaned from other experiments ; thus, by a combination of all the available evidence, a picture is gradually formed of the nature of the unknown compound, rather as a pathologist will build, bit by bit a picture of a person long dead, from the skeleton and fragments of clothing.

From the foregoing it will be apparent that the larger the difference in R_F values between components of a mixture, the better will be the separation. In complex mixtures it is usual to find that not all the components have been separated, as some have R_F values so close together that there is considerable overlapping of spots. To overcome this difficulty, Martin and his colleagues proposed using what is called a two-dimensional chromatogram. The mixture to be analysed is applied at one corner of a rectangular sheet of paper and chromatographed as usual in a large tank. This results in a chromatographic pattern along one side of the sheet with some of the spots only partially separated. The sheet is now turned through a right angle and chromatographed again with a different solvent specially chosen to separate those spots which came together in the first solvent. The effect of the second solvent on spots already separated in the first run is of no importance because these being spaced apart cannot come together again in a direction at right angles to their original path. The result of such a procedure is to spread the spots over the sheet of paper. Identification is usually done by reference to a map produced by running a similar chromatogram using a mixture of known compounds, but other methods are available.

It was pointed out earlier that a great merit of paper chromatography is its acceptance of minute quantities of material. This advantage for analytical studies is at the same time a disadvantage for work on a larger scale where it is required to isolate weighable amounts of the components of a mixture. The scale can be increased by working with very thick paper which will handle some thousandths of a gramme of material. If it is required to work with gramme quantities it is usual to employ columns packed with cellulose powder or even starch. Other materials can be used. The operation of the column is identical with that already described for silica gel.

Perhaps one of the greatest merits of chromatography is its extreme flexibility. The alternatives given in this discussion merely scratch the surface of the total of those possible. Thus, it is wonderfully adapted as a tool for those working in many diverse fields. Separations on paper sheets may be assisted by passage of an electric current—a process known as electrophoresis ; complex compounds originating from natural sources may be purified on a very small scale by paper chromatography, the pure compound leached off the paper, broken down by chemical methods and the fragments identified by chromatographing again on paper.

In an ever increasing number of cases chromatography is being made strictly quantitative. Space has not allowed of more than a mention of the use of ion exchange resins, but every form of

Fig. 1(*a*)

Fig. 1(*b*)

Fig. 1

A separation of coloured substances on a chromatographic column.
(*a*) Initial stage. The mixture to be separated has been absorbed on to the top of the column and already a very thin band has separated.
(*b*) Some time later. The components of the mixture have separated into bands

[*face page 182*

FIG. 2

A paper chromatogram during development. Two papers are being run simultaneously and the position of the solvent front can be seen.

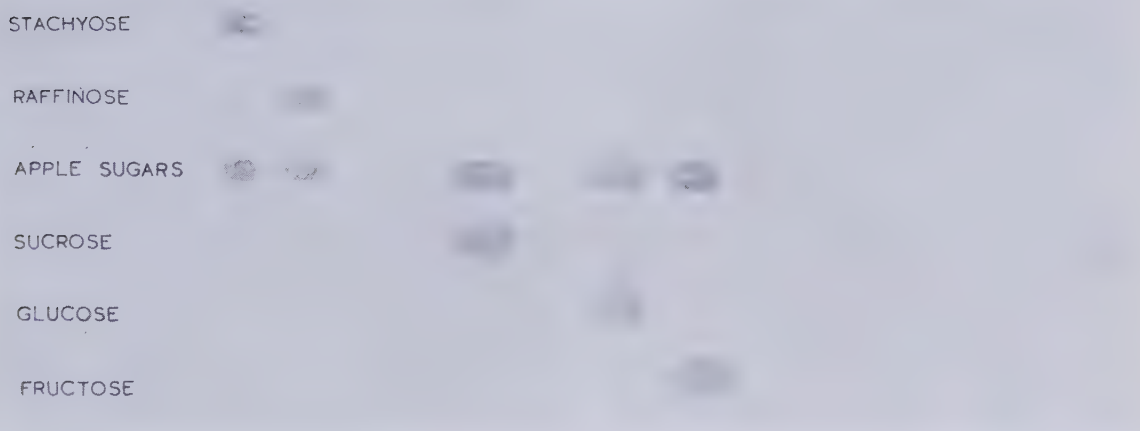


FIG. 3

A paper chromatogram showing the separation of sugars from 1-year-old dormant shoots of an apple variety, and illustrating the use of markers to identify each spot

chromatography as it is developed and extended has great potentialities in the search for knowledge of how plants live, feed, produce fruit, fight foes and even why they die. There is an ever recurrent thrill as each new chromatogram is run, opening perhaps a little wider the crack through which glimmer fresh fields of knowledge.

Further Reading

Readers may find the following helpful for further reading and references :

(1) Martin, A J. P. *Endeavour*, 1947, **6**, 21.
(2) Tiselius, A. *Endeavour*, 1952, **11**, 5.
(3) Williams, T. I. *An Introduction to Chromatography*. Blackie & Son Ltd., London, 1947.

WEED CONTROL UNDER FRUIT TREES

By G. C. WHITE

In arable orchards, it is usual practice in the spring to fork out weeds which are not controlled by the cultivating implement. Further control of weed growth is done by hoeings, the number depending on the vigour of the weed growth and the available labour. Likewise in grass orchards, grass around the trunks, not controlled by mowing, is usually cut by hand at least once during the season.

There seems to be no clear evidence to show any beneficial effects of controlling weed growth around the trunks, except in the case of young trees, where competition for nutrients and moisture may seriously affect tree growth. With older trees, the area in question is usually occupied by the scaffold roots of the tree, thus competition for nutrients would only have a limited effect on the trees, but the damage due to certain pests, notably Dock Sawfly, and to such diseases as Collar Rot, could conceivably be lessened by controlling these weeds.

In view of the ever-increasing cost of labour, it seems desirable to replace the traditional methods of weed control, which are time-consuming, by a method that reduces the amount of hand labour. Although not giving an absolute control of weed growth, the use of herbicidal sprays seems promising in this respect.

Oil sprays have been employed in Californian citrus orchards for over-all weed control for many years, with considerable success. In view of this success, various types of oil sprays have been tried for controlling weeds around the trunks of established trees. From the results so far obtained the following points are of interest :

1. Of the oils tested, Diesel oil and Tractor Vaporizing oil (T.V.O.), either alone or mixed in equal parts, seem to be the most useful. T.V.O. is more rapid than Diesel oil in producing contact injury, but may be less effective in causing ' chronic ' injury to the parts of the plant below ground.

2. If possible the sprays should be applied on hot sunny days ; during dull periods Diesel oil or the mixture should be used in preference to T.V.O.

3. The weeds should be sprayed after they have started growth in the spring, when they are 4 in. to 6 in. high ; they should *not* be left until they have developed to 15 in. or 18 in. The volume of oil needed is less and a better cover can be obtained at an early stage of growth, and the weeds are then more susceptible to the oil sprays.

4. The oil should be applied to give an adequate wetting of the foliage without excessive runoff on to the soil ; this should not require more than 200 gallons of oil per acre of the sprayed area. Examples of the amounts to apply in orchards of several different spacings are given in Table I. Thus, for trees planted 20 ft. × 20 ft., i.e. 108 trees per acre, 8 gallons per acre will be required to spray 4 ft. squares around the trunk. It is important to avoid run-off not only because it is wasteful of oil, but also because it may have harmful effects on the soil micro-organisms and possibly on the trees themselves.

TABLE I

VOLUME OF SPRAY, IN GALLONS PER ACRE, REQUIRED TO GIVE 200 GALLONS PER ACRE ON THE SPRAYED AREA

Planting distance	Number of trees per acre	Area per tree to be sprayed and corresponding gals. per acre		
		3 ft. × 3 ft.	4 ft. × 4 ft.	5 ft. × 5 ft.
12 ft. × 12 ft.	302	12·5	22·2	34·7
15 ft. × 15 ft.	193	8·0	14·2	22·2
18 ft. × 18 ft.	134	5·5	9·9	15·4
20 ft. × 20 ft.	108	4·5	8·0	12·4
24 ft. × 24 ft.	75	3·1	5·5	8·6

5. The application should be as a fairly coarse spray, so as to prevent drifting on to the foliage of the trees. Scorching of the leaves will occur if oil droplets contact them. Care should be taken to avoid excessive wetting of the trunks since bark damage may occur, especially on young trees.

6. Regrowth from certain perennial weeds should be sprayed again when growth is 4 in. to 6 in.

high ; thus it may be necessary to apply three or more oil sprays during the season to obtain a satisfactory control of couch grass.

Our experiences of these oils is limited at present and growers are advised to try the effects of the various oils on small areas before making large scale applications. Particular care should be taken with young trees, as their bark may be more easily damaged.

Summary

Suggestions are made for the use of oil sprays for the control of weeds around the trunks of fruit trees.

PROGRESS IN RESEARCH IN FRUIT CROPS IN 1956

By H. B. S. MONTGOMERY

The progress of research during the past year is reviewed in Part II of this Report. A number of the items of more practical interest have been collected in this article for the information of fruit growers.

Rootstocks

Apples

A recent survey of every tree in the classical rootstock trials has shown very few to be carrying rubbery wood virus. This is good news for had many been found, the real effects of some of the rootstocks on vigour might have been in doubt.

There has been much scientific argument on the relative importance of the stem and root in determining rootstock influence. A trial with Lane's Prince Albert on M.IX, M.II, and M.XII has shown that the main rootstock influence comes from the roots but that the rootstock stem slightly intensifies this influence. These results have been published (E445). Many of the growth studies referred to on p. 188 also have a bearing on this subject.

Pears

The original trial of Conference on Quinces A, B, and C is now 36 years old, and the results are reported on p. 91. These trees were planted at 12 ft. square and as they had become very crowded the alternate trees in each row were removed in 1955. The trees have responded with the largest crop per tree that they have ever had, and have also grown well. The trial comparing clonal *pear* rootstocks with Quince A, now 10 years old, carried a moderate crop this year ; trees on pear stock tended to produce smaller fruits that were more infected by scab than did trees on quince. A few pear trees on *apple* rootstocks are being grown under observation in the nursery ; they are now three years old and have fruited.

Plums

Ten-year-old trees of Cambridge Gage and Marjorie's Seedling gave 100 lb. per tree on Marianna, and 75 lb. per tree on St. Julien A. Victoria on Common Plum and St. Julien A gave 60 lb. per tree.

Cherries

An experiment reported on p. 63, has shown that we must look to mazzards if we require well rooted trees. The search for less vigorous mazzards is proceeding and a new trial is being planted in the winter 1956–57 to test two mazzard rootstocks of differing vigour, as well as certain cultural and manurial treatments.

Microscope studies

The detailed examination of the microscopical structure of shoots of the Malling-Merton rootstocks has revealed that the shape and thickness of the walls of certain cells lying slightly below the surface of the bark (collenchyma cells) are related to the resistance of the stock to Woolly Aphid.

Propagation

Recent work on this subject was presented on the Members' Day in June, so that space need not be given to it here.

Fruiting and biennial bearing

Too little is known about how a fruit crop develops, and new work is aimed at studying its development right from the very beginning up to flowering, pollination and fruit setting, and growth. This work will assist the investigations on biennial bearing, which at present are largely concerned with reducing the leaf-area with copper sulphate sprays at the right time to reduce the number of fruit buds that form, and with thinning the crop by means of blossom sprays. No reliable sprays for blossom thinning have yet been found for our conditions, but several, including DNC, can be used

for the complete removal of blossom without harmful effects in later years. This treatment might be used to change the year of cropping of biennial trees so as, for instance, to get half the trees in an orchard ' out of step ' with the rest, but further trials are necessary before it could be used on very young trees or could be repeated year after year.

Late blossoming apples

With a view to breeding varieties that flower after the main risk of spring frost is over, about 10,000 apple seedlings have been raised each year since 1954. The time of blossoming can be predicted fairly well from the time of leafing out, so these seedlings are being selected on this basis ; some 950 late leafing seedlings have been retained from the 1954 batch, and are being grown for fruiting.

Varieties

A small trial has been planted of Cox's Orange Pippin propagated from trees of differing cropping and blossoming history. If these characteristics persist in these new trees, the whole question of strains of varieties is likely to come up for serious consideration.

Marjorie's Seedling proved to be the heaviest cropping plum this season with 670 lb. per 21-year-old tree on Myrobalan B. Ontario, 19 years old, gave over 300 lb., Warwickshire Drooper, Cambridge Gage, Denniston's Superb and Comte D'Althann's Gage over 250 lb., and Victoria, Jefferson, Old Transparent, and Bryanston Gage 200 lb. per tree.

Soft fruits

Strawberries

Cultural trials with strawberries have been continued, including manuring with nitrogen, irrigation, deblossoming, burning and cutting over after fruiting, and planting systems (see p. 173). A weedkiller trial was begun on two-year-old Royal Sovereign plots. Here SES (sodium 2,4-dichloro phenoxyethyl sulphate), applied monthly at 3 or 5 lb. per acre, except while the fruit was ripening, controlled fat-hen, nettles, and groundsel without any harmful effect on the crop or the plants.

With strawberries the new heat-treated clones are of special interest. Three-year-old plants of heat-treated Huxley and Perle de Prague grew and cropped better, but those of Early Cambridge, after cropping more heavily in their maiden year, subsequently carried many blind crowns. This trouble is now being investigated and seems to be associated with seasonal conditions and not with heat treatment, as several varieties that had not been heat-treated also developed blind crowns. Heat-treated clones of other varieties continued to show improved growth and cropping due to inactivation of the virus, but there was a tendency for the increased leafiness of the plants to delay fruit ripening a little ; this may be important with early varieties. Cambridge Regent was particularly badly affected by *Botrytis* rot.

Cane fruits

Five new selected Loganberry clones, now under field trial, made good growth during their first year. Four further clones are being tested for virus and are being propagated for cropping trials. The Thornless Evergreen blackberry from Oregon, U.S.A., is being tested for virus.

The raspberry breeding work is directed to building up parents containing all the desired characters. Thus seedling 30/8, produced by a cross between a seedling from self-pollinated Pyne's Royal and one from self-pollinated Lloyd George, shows good vigour and large fruit in its self-pollinated progeny for three generations. Resistance to the Raspberry Aphid (*Amphorophora rubi*), thornlessness, and fruit quality are now being bred into this and other lines.

Frost damage

Spring frosts on 7th, 20th, and 30th April, and 21st May damaged walnuts, Durondeau pears, and some black currants, and caused blemishes that affected quality in other fruits. The reduction in blemishes within an area protected by an automatically controlled range of sprinklers showed the effectiveness of this protection device.

Different varieties of fruit have been tested in the laboratory for resistance to winter and spring frosts. In experiments designed to throw light on the underlying causes of frost resistance of blossoms, special chambers with controlled temperature and artificial light were used to give apple trees in pots different degrees of hardening before subjecting them to freezing temperature at blossom time. Blossoms from the same trees were analysed for water and sugar content before freezing. Work on the influence of mineral nutrition on frost resistance has been begun with Royal Sovereign strawberries and Crawley Beauty apples grown in sand culture.

Mycorrhiza

The roots of many plants, including fruit plants, are invaded by certain fungi that appear to cause no injury to the plants and that may be beneficial in some cases. Such roots are called mycorrhiza. Apple cuttings grown with and without mycorrhiza indicated that these affected the relative amounts of different nutrients absorbed by the roots, though the main effects on composition showed in the roots. It is not yet known whether mycorrhiza are beneficial under orchard conditions.

Disease resistance

Collaborative work between the Biochemistry and Plant Pathology Sections has produced very interesting results on the relationship between the fungi causing scab and their hosts, apple and pear. One naturally occurring compound, chlorogenic acid, has amongst others, been found to stop the development of these fungi ; tests in culture showed that its toxicity was due mainly to one part of its molecule. A number of compounds having a similar sort of molecule were then examined and they showed that the toxicity was increased when certain changes were made in the molecules. By following up these indications, cinnamic acid, one of these compounds that is comparatively cheap and readily available was found to be outstandingly toxic to the scab fungus. The possibilities of protecting by patent the use of cinnamic acid and related chemicals for horticulture are being explored with the help of the National Research Development Corporation.

Nutritional work

A Members' Day in September was devoted to soil management, and amongst other developments it revealed the advances being made in the study of soil moisture conditions under the different treatments.

The experimental watering of trees of Laxton's Superb over four years has shown a cumulative effect on cropping so that, even in the relatively wet summer of 1956, the wettest watering treatment gave 70 per cent more fruit of good market size ($2\frac{1}{4}$–3 in.) than did the unwatered trees. With Laxton's Fortune it was found that watering and high nitrogen applications achieved similar results, trees receiving either of these treatments giving heavier crops than those with low nitrogen without supplemental watering.

A note on the control of weeds round the trunks of apple trees appears on p. 184.

A new experiment is being started on the effects of straw mulch and irrigation on Malling Exploit and Jewel raspberries.

Spraying with 2 per cent magnesium sulphate at fortnightly intervals prevented the appearance of leaf scorching on dwarf pyramid Edward VII trees on M.VII rootstock. Spray treatments on stoolbeds of M.IV and MM.102 rootstocks also reduced leaf scorching ; in addition the shoots were thicker and there was less mildew in the sprayed plots.

Growth studies

Investigations are continuing into the growth and development of leaves, shoots, fruit-buds, etc., of fruit trees as influenced by rootstock, deblossoming treatments, and various degrees of pruning and defoliation. In comparing the growth rates of different rootstocks, a complicating factor is introduced by the different times of bud burst and leaf fall of each rootstock. To study this, trees of M.II and M.XVI, grown in pots, were given special cold storage or forcing treatment to bring them into leaf together. From this experiment, it appears that the total growth made is related to the length of the growing season, and not to any fundamental difference in the efficiency of the plants.

A difficulty in this work has been the lack of any suitable method of measuring the amount of sugars, starch, and other carbohydrates manufactured in the leaf and the amounts lost in normal respiration. A new piece of apparatus has now been constructed by which it is possible to measure either of these processes for a single immature leaf over a period of a few minutes.

Fruit splitting in plums and cherries

Experiments on the effects of the hormone NAA on fruit splitting yielded few results this year, partly because splitting on the untreated fruit was low, possibly because of the cool season, and partly because rain interfered with the application of the sprays at the intended times. There was no evidence that NAA reduced splitting.

Spray damage

Leaves of several varieties grown on different rootstocks in various parts of the Research Station

were tested for their susceptibility to damage by copper sulphate. The most striking result obtained was the lack of any effect of rootstock.

Entomology

A special study of Pear Sucker (*Psylla pyricola*) has shown that there is only one species of this pest on pears. It has three generations each year and overwinters as an adult.

The experiment on the effects of fungicides on orchard fauna at Stondon Massey, Essex, has ended. After four years' treatment with routine lime-sulphur sprays, the populations of the Fruit Tree Red Spider Mite had developed from a very low level to produce conspicuous bronzing of the foliage, while with captan over the same period, a constant low level was maintained. Records were kept of insect predators throughout the period. Similar records have been made for a number of years in a neglected orchard in Kent, and this year one half of the orchard has been cleared of undergrowth to see what effect this has on the insects and mites on the trees.

The Black-kneed Capsid, *Blepharidopterus angulatus*, was responsible for the great reduction in the numbers of Fruit Tree Red Spider Mites on a plot at the Research Station used for the study of the combined effect of insecticides and fungicides on this pest. The predator fed readily on leaf-hoppers and so maintained itself in large numbers when the supply of red spider mites was low. In studying the Black-kneed Capsid, a method is used of marking the insects with tiny spots of coloured paint ; they are then released and can be identified when they are subsequently recaptured. This method was used to compare the survival of the capsids under conditions where they were very plentiful and where they were very scarce.

A new study is being made of the Black Currant Gall Mite, with special attention to the early summer when the mites are spreading from the ' bug buds ' on to the leaves and developing buds. Selected acaricides are being tested in a search for more effective control measures than the pre-blossom lime-sulphur now recommended.

The life cycle of the Strawberry Seed Beetle has now been worked out in detail and more attention is being given to the other ground beetles found in strawberry beds. No satisfactory control measure has yet been discovered ; dieldrin cannot be recommended because of the high residues on the ripe fruit. A steep-sided trench lined with sprayed straw was tried unsuccessfully as a trap to exclude beetles from strawberry beds.

Other insects on which research is in progress include aphids, leaf-hoppers, Codling Moth and tortricid moths.

Fresh light is being sought on three unexplained problems that occur locally in Kent, namely, a slow decline of apple trees, a failure of young cherry trees planted where cherries have been grubbed, and poor root development and decline of strawberries. Similar troubles in various parts of the world have been put down to eelworms, the so-called ' Soil Migratory Nematodes '. Samples of soil and roots from each site have, therefore, been examined for eelworms and in each case some or all of the following three kinds have been numerous : Root Lesion Nematodes, which invade and multiply in the outer layers of the root of all three host plants, and Stylet and Pin Nematodes both of which rarely invade the roots but feed on the outside of them. A marked increase in vigour and root health can be obtained by freeing the soil from eelworms by fumigants or gentle heat. It is not yet possible to say to what extent this is due to control of the eelworms or to other effects of the treatments on the soil.

Spray chemicals

The application of spray chemicals as concentrates, which has been shown to be effective with fungicides in controlling Apple and Pear Scab, has now been shown to be effective also with *gamma*-BHC, aldrin, or endrin, in water or neat lime-sulphur, against Apple Sawfly.

The preblossom spray containing 0·025 per cent DDT and 0·007 per cent of *gamma*-BHC, with a very efficient wetter, which was evolved at Long Ashton for the simultaneous control of caterpillars, capsids, aphids, and sucker, was tried at mouse-ear stage and green cluster. The results suggest that the concentrations of the insecticides, especially of DDT, may be too low for reliable control under our conditions.

In a preliminary trial, ryania (powdered stems of *Ryania speciosa*) appeared to be better than lead arsenate in controlling Codling Moth, but not so good as DDT. In Canada, it is claimed that this new insecticide has an advantage over DDT in that it is not so harmful to beneficial insects.

Methods are being evolved for testing chemicals against Apple Mildew under greenhouse conditions over as long a season as possible. A test of cinnamic acid at 0·1 per cent showed that this promising material for scab control offers little hope of also controlling mildew. In a field trial of DNOPC (sometimes referred to as Karathane) on summer-pruned dwarf pyramids that has been running for three years, overwintering mildew has been reduced to negligible levels.

Diseases

In work on Bacterial Canker of cherries, the antibiotic streptomycin proved to be slightly less effective than Bordeaux mixture in killing bacteria on the surface of leaves in early autumn and in reducing canker infections. Bordeaux mixture gave a better control than any previously obtained, although it was used at a low strength, and this was attributed to the earliness of these autumn sprays. Further experiments suggest that streptomycin can penetrate the leaf and prevent the development of bacteria already established inside (see p. 170).

Cinnamic acid (see p. 188), applied as a low volume spray at 0·2 per cent to apple and pear trees under glass, caused no damage and reduced the incidence of scab. It gave this good result whether the spray was applied before or after the leaves were inoculated, thus suggesting both protective and eradicant effects. Field trials with this material have not yet been fully evaluated.

Spore-trap and weather records were taken as part of a regional trial in co-operation with Dr. J. M. Hirst of Rothamsted. These records will be related to the incidence of scab on Bramley's Seedling apple trees.

The further development of low-volume spraying has been the investigation of the effects of different droplet-sizes on scab and mildew using special equipment designed by the National Institute of Agricultural Engineering. If droplets rather larger than 50μ, at present regarded as the desired size, prove effective and safe, considerable savings could be made in the cost of the machines to apply these sprays.

Applications of captan in July, August, and September, 1955, reduced the numbers of fruits developing *Gloeosporium* rots in storage. The control achieved by one spray in September was not appreciably improved by an additional spray in August.

Virus diseases

An important gathering of European workers on virus diseases of tree fruits took place at East Malling in early July, to examine and discuss our range of plants infected with and showing symptoms of specific diseases. This meeting agreed on a selection of plants to be used in testing fruit trees for virus, and attempted to sort out which diseases were the same in the different countries.

One of the newly-recognized diseases, Starcrack of apples, seems to be more prevalent in orchards than was suspected. Leaf Roll of cherries has been found in eight Kentish orchards and a large number of the trees in these orchards are affected by Leaf Roll and Rasp Leaf.

A canker disease on cherries, resembling Bacterial Canker, has been found to have the characteristics of a virus and is believed to be the cause of the spur cankers that are so common on Noble cherry trees.

Three apparently virus-free selections of Common Plum have been made; this is good news for those who wish to grow Cambridge Gage on this rootstock, for this gage is very susceptible to the Bark Split virus carried in many Common Plum rootstocks.

Work on the Green Petal disease of strawberries was accelerated by a visiting research worker from California, Dr. Norman Frazier, who is an authority on virus diseases of strawberries in U.S.A. and their insect vectors. The evidence at present suggests that more than one virus or virus strain is responsible for this disease, and that they normally occur in clover and many other wild and cultivated plants. They are transmitted by leaf-hoppers that feed occasionally on strawberries but mainly on other plants.

An issue of virus-tested runners of Talisman and Cambridge Prizewinner was made to the Nuclear Stock Association this year, along with six other varieties. Merton Princess has been propagated for issue of tested runners in 1956–57.

Fruit storage

A large number of samples of Cox's Orange Pippin from experimental plots and commercial orchards have been examined after varying periods in storage. In general the keeping quality was improved by swards and the omission of nitrogen applications as regards rots, and by potash applications as regards breakdowns. With Laxton's Superb, fruit grown with grass or arable showed less rotting than that grown with straw mulch. Scarcely any breakdown occurred with this variety even when stored at 32° F. Research is directed towards finding out what are the effects of these and other treatments on the fruits themselves that result in the changed storage quality; in this, chemical composition, respiration, and cellular structure of the fruits are being examined. All this work is being done jointly with the Ditton Laboratory.

General

Several Sections, especially Statistics and Plant Analysis, play a big part in the work of other Sections, and the research they conduct tends to concern methods of examining results or the com-

position of plants, and so to be of less direct interest to growers. This work is, however, essential to the more practical aspects of the progress described above.

Summary

Those aspects of the reports of the Research Sections for 1956 that deal with fruit are presented in popular form for fruitgrowers.

PROGRESS IN RESEARCH ON HOP DISEASES IN 1956

By R. V. HARRIS

This is a review of items of special interest to hop growers in the general research report of the Plant Pathology Section for 1956 (p. 25).

Progressive Verticillium Wilt

Improved wilt-tolerant varieties

This year's work with Wye College has brought us within sight of completing the first stage in the testing and selection for wilt-tolerance and cultural characters of the 2,000 specially bred seedlings on which we jointly started work in 1950. The best of these will then be planted out for large-scale farm and brewing trials. Meanwhile, the advanced trials of our 'stop-gap' seedlings were carried to a stage when a decision on the release of two of them, seedlings D1 and D3, can be expected in the winter 1956–57. By then a nucleus of healthy sets will be ready for issue to the Specialist Hop Propagators.

Wilt tolerance

The *Verticillium* fungus was isolated from a number of known progressive outbreaks and inoculated into Fuggle using the special concrete tanks constructed for such testing. Usually Fuggle is as sensitive in these tests as it is in hop gardens, but for some unknown cultural cause these Fuggle plants acted as a tolerant variety.

One of the ways in which a tolerant variety apparently bars the progress of the fungus through the plant is by the formation of balloon-like growths, known as 'tyloses', within the water-conducting parts of the stem. Microscope examination of these Fuggle plants from the infection tanks showed that they also had 'tyloses'. The fact that this defence reaction can be brought into play even in a sensitive variety by causes other than the invading fungus was further confirmed this year when tyloses were produced in response to small cuts made into actively growing Fuggle bines in a normal hop garden.

Direct control

Before methods of eliminating the fungus from infected hop gardens can be improved it is necessary to know how and where the fungus exists outside the hop plants: what other plants can it invade and can it survive in the soil apart from these host plants?

Early experiments, in 1955, showed that it can live in the roots of common weeds of hop gardens, such as groundsel and fat-hen, without producing any marked wilt symptoms. They also showed that in the soil it does not form resistant bodies that can remain infective over a long time. It does, however, produce large crops of minute thin-walled spores as it grows out of infected plant debris. These can be carried about in the soil water but it seems likely that they germinate only in the vicinity of plant roots. These findings suggest that the persistence of the fungus in the soil largely depends on the presence of its natural host plants, and this clearly opens up possibilities of starving the fungus out by removing all these plants; the fact that they include common weeds complicates this task.

During this year three important advances were made. First, a field experiment was started to see if the fungus could be 'starved out' of the soil, using various cropping and soil treatments designed to keep all the host plants out of the picture. Secondly, by growing plants with their roots in special glass-sided observation boxes it was observed that the abundant production of spores outside the infected plant did not vary under different soil conditions. Thirdly, an attempt to control the disease directly by soil and plant applications of the antibiotic griseofulvin was completely ineffective.

Virus diseases

Spread of Nettlehead

Many plant virus diseases are spread by insects, but although Nettlehead is caused by a virus, and it appears and multiplies in hop gardens, we have so far failed to find any such natural agent or vector. All the commonly occurring insects and mites in gardens with Nettlehead have been used in attempts to carry the disease across from a Nettlehead hop to a healthy hop but without success. These attempts, however, reconsidered in the light of the accumulated information from surveys of infected gardens, suggest that the main source of the virus may not be the hop plant at all

but some other plant, possibly a herbaceous weed, outside the hop garden. An outbreak of Nettlehead in a hop garden would then start with the chance feeding on a hop plant of insects normally living on some infected weeds outside the garden, and further spread within the garden might continue from infected weeds growing within the garden itself.

To test the truth or otherwise of this idea, this year's research was devoted to recording the weeds found in infected hop gardens and those in the vicinity of such gardens that were showing suspicious symptoms. The latter were grafted to Early Prolific, a variety that is very sensitive to Nettlehead, to find if they contained Nettlehead virus.

Summary

Research on *Verticillium* Wilt and the Nettlehead virus disease, more fully described in the general research report of the Plant Pathology Section for 1956, is briefly reviewed for hop growers.

INDEX

Abscission, 20
Aldrin, 35
Amos Memorial Lecture, 41
Amphorophora rubi, 13, 32
Analysis of fruiting, 11
Analytical methods, 24
Anatomical investigations, see under Histological investigations
Anthocoris nemorum, 31
Aphids, 5
Aphis fabae, 28
Apple Blossom Weevil, 31
—— cuttings, rootstock effect on regeneration of, 60
—— leaves, measurement of copper damage, 109
—— manurial trial, 39
—— Mildew, 28, 29, 37
——, new dessert, growth and cropping of, 81
—— Sawfly, 32, 35
—— Scab, 5, 25, 161
—— ——, spore trapping, 20
—— —— systemic fungicides against, 29
—— Sucker, 32
—— uniformity trial, 17
—— varieties, 12
Apples, 3, 4
Arable crops, 6

Bacterial Canker, 5, 25
—— —— use of streptomycin for, 170
Bark Split virus, 10
Beneficial insects and mites, 31
BHC, 5, 32, 35
Biennial bearing, 4, 11
Biochemistry Section, 21
Blackberries, 13
Black currant, 4
—— ——-gooseberry hybrid, fertile, 73
—— -kneed Capsid, 31
Blepharidopterus angulatus, 31
'Blindness' in raspberry jam, 10
Blossoming periods of tree fruits, 89
Bordeaux mixture, 5, 25
Boskoop Research Station, Holland, 19
Botrytis cinerea, 4, 12, 13, 36
Branch breakage, 18
Breeding, 11, 12, 13, 73
Bud-break, 18

Caffeic acid, 25
Cane Midge, 5
—— Spot, 5
Captan, 5, 31, 36
Cauliflower Disease, 25
Cereals, 6
Chat Fruit, 27
Cherries, 3, 10
——, sweet, *Prunus* spp. as rootstocks for, 63
Chlorbenside, 5, 37
Chlorbenzilate, 35
Chlorfenson, 37
Chlorogenic acid, 25
Chromatography, development of, 179
Cinnamic acid, 21, 25, 30
Cladosporium sp., 29
Clay-coloured Weevil, 5
Clones, maintenance of strawberries, loganberries, blackberries, 13
Codling Moth, 5, 32
Collar Rot (apples), 27, 168
Concentrate spraying, see under Low-volume spraying
Conference pears, 36-year-old trees on quince rootstocks, 91
Copper damage in apple leaves, measurement of, 109
—— oxychloride, 27
—— spray, 5
—— sulphate, 20, 27
Corynebacterium fascians, 25
Crag herbicide, 14
Cropping, growth, of some new dessert apples, 81
Cultural measures, strawberries, loganberries, 14
Cuprous oxide for spraying, 5
Currant breeding, 13
Cuttings, apple, rootstock effect on regeneration of, 60
——, controlled winter storage of, 101
——, hardwood, 7, 101
——, leafy, 11
——, ——, mist propagation frames for, 54
——, softwood, 7
Cytology, 14

DDT, 5, 32, 35
——, persistence of, 152
Deblossoming, effect on growth, apples, 18
——, effect on crown production, strawberries, 14
Derris, 5
Dieldrin, 35
Ditton Laboratory, 39
DNC, 5
DNOPC, 29, 37
Double-shield budding, 6
—— -working, 6

Ecological studies on Fruit Tree Red Spider Mite, 31
Eelworms, 25
Endrin, 35
Entomology Section, 31
Experimental design, methods of, 16
—— glasshouses, 7
—— nurseries, 6
—— orchards, 3

Fenson, 37
Frost blemishes, 14
—— damage investigations, 14
—— —— research equipment, 93
Fruit drop, 3
—— marketing, 4
—— Nutrition Section, 22
—— splitting, 20
—— Storage Investigations, 39
—— thinning, 39
—— Tree Red Spider Mite, 5, 31
Fungicides, 36

Gale damage to tree fruits, 85
Gall Mites, study of, 33
Gloeosporium spp., 29
Gooseberries, breeding of, 13
Green Petal Disease, 28
—— Mottle, peach, 27
Gregory, Prof. F. G., 41
Griseofulvin, 26, 30
Ground Beetles, strawberries, 33
—— —— ——, control of, 142
Growing season, 7
Growth, 3
—— and cropping of some new dessert apples, 81
—— studies, 18
—— substances, 19
Grubbing on Expt. Farm, 4

Hailstorm, 3, 19
Harpalus rufipes, 33
Harvest apple, 81
Heat treatment, strawberries, 12
HETP, 7
Histological investigations, 10
History of Station land, 49
Hop diseases, research on, 192
—— virus diseases, 28
Hoplocampa testudinea, 32
Horticultural meteorology, 15
Host-parasite relationships, 21

IBA alcoholic dip, 10
Incompatibility, 10
Insecticides, 35, 36
Insects, notes on interesting, 131
Iron deficiency, 7
——, supply, varying, 22
Irrigation, 4
Isoquercitrin, 21

Karathane, 5, 29

Land uniformity, 16
Lead arsenate, 5
—— —— mercurated, 5
Leaf areas, 18
Leafhoppers, 32
Leaf sampling technique, 24
—— Roll cherry, 27
Leafy cuttings, propagation under mist, 11, 54
Lime-sulphur, 5, 7
Line-pattern, hops, 28
Loganberries, 13
Low-volume spraying, 28

Magnesium deficiency, 22
—— supply, varying, 22
Malling-Merton, M.IX cross rootstocks, 9
Manurial trials, 22
Manuring, 4
—— in relation to apple storage, 39
Metasystox, 5
Mildew, Apple, control of, 29
Mineral composition of fruit plants, 24
Mist culture, 18
—— propagation frames for leafy cuttings, 54
Mites, predacious, 33
Mosaic (hop), 28
Mycorrhiza, 14

NAA, 20
Nabam, 146
Nematodes, 33
Nettlehead Disease, hops, 28
Nicotine, 7
Nitrogen, concentration in scion bark, 24

Operophtera brumata, 32
Organic mercurials, 35
Ovicides, sprays, 5

Peaches, frost damage, 14
Pear, Conference, 36-year-old trees on quince rootstocks, 91
——, low-volume spraying, 29
—— on apple rootstocks, 9
—— Psylla, 31
—— Scab, 25
—— Sucker, 135
Pears, 3, 5
Peas, 6
Perforation plates, scalariform, 10
Phloem anatomy, 10
Phosphorus, concentration in scion bark, 24
Photometer, for estimating area of detached leaves, 107
Photosynthesis, 19
Phytophthora cactorum, 27
Phytotoxicity, 37
Picking dates, 3
Plant Analysis Section, 24
—— Pathology Section, 25
—— Physiology, place in fruit growing, 41
—— —— Section, 18
—— Protective Chemistry Section, 35
Plantings, fresh, 4
Plum line-pattern, 28
—— rootstocks, semi-dwarfing, 10
—— —— description and classification of, 75
—— varieties, 12
Plums, 3, 5
Podosphaera leucotricha, prevalence of, 22
Polythene, 7
Pomology, review of research work, 9
Potatoes, 6
Pre-blossom sprays, 35
Predacious spiders and mites, 175
Propagation, mist frames for leafy cuttings, 54
——, rootstocks, aspects of, 101
Pruning, 11, 39
Prunus aphid, 32
Pseudomonas mors-prunorum, 25
Psylla mali, 32
—— *pyricola*, 31

Quince rootstocks, 9
—— ——, 36-year-old Conference trees on, 91

Rasp Leaf, cherry, 27
Raspberry, 4
—— Aphid, 10
—— breeding, 13
—— varieties, 13
Research progress in 1956, 186
Respiration, 19
Root nutrition, 19
Rootstocks for cherries, 63
—— and scion incompatibility, 21
—— —— —— reaction, 18
—— effect on regeneration of apple cuttings, 60
—— effect of, on susceptibility to scab, 4
—— Malling-Merton, 9
——, plums, description and classification of, 75
—— M.IX crosses, 9
—— new, testing of, 9
Rubus virus diseases, 28
Ryania, 32

Scientific Liaison Section, 38
Scion varieties, 20
—— influence on stock, 10
Scorching due to spray, 5
S.E.S., 14
Silver Leaf (plum), 29
Soil management studies, 23
—— —— in relation to storage, 39
—— moisture, 23
—— uniformity, restoration of, 23
Sphaeroblasts, 10
Spiders and mites, predacious, 175
Splitting, fruit, 20
Spore germination tests, 146
Spray damage, 20
—— programme, routine, 5
Sprinklers in frost damage investigations, 14
Spur Blight, raspberries, 13
Statistics and Records Section, 16
Stereum purpureum, 29
Stool shoots, 11

Storage, cold, 4
——, cuttings, controlled winter, 19
——, gas, 4
——, protected, 10
Strawberries, 3
Strawberry Aphid, 32
—— Botrytis, 4, 30
—— Ground Beetle, 36
—— —— ——, control of, 142
—— Mildew, 5
—— Mosaic, 28
—— planting, 173
—— Seed Beetle, 33
—— varieties, 12
—— viruses, 28
—— ——, heat treatment, 28
Streak, strawberries, 12
Streptomycin, 25
Sulphur, flowers of, 7
——, resistant and sulphur-shy apples and gooseberries, buffer capacity of pH of, 114
—— spraying, 5
Survey of commercial fruit, 39

Tar-oil, 7
Tetranychus urticae, 28
Thinning, fruit, 11
Thiram, 30
Tortricid moth, 32
Transient yellows, strawberries, 12
Trunk-cutting studies, 23
Tydeman's Late Orange, 81
—— Early Worcester, 81
Typhlodromus tiliae, influence on Fruit Tree Red Spider Mite, 31

Vegetative propagation, 19
Venturia inaequalis, 25, 36
—— *pirina*, 25
—— spp., 21, 125
Verticillium Wilt, fruit plants, 26
—— —— hops, 26

Walnuts, 14
—— frost damage, 15
Water-culture, 18
Weather conditions, 3, 4, 97
Weedkillers, 23
——, expt. on strawberries, 14
—— control among fruit trees, 184
Whitbread's Golding Hop; wilt tolerance and establishment of wilt-free stock, 128
Wind, effect of, 3
Wind rocking, 17
Winter Moth, 32
—— storage of hardwood cuttings, 101
—— —— of cuttings, controlled, 19
Witt, A. W. an appreciation, 1
Woolly Aphid, rootstocks resistance to, 10
—— —— resistant apple seedlings, 31

Yellows, transient strawberry, 12

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The current VOLUME 32 (1957) contains papers from both the sponsor Research Stations, from the John Innes Horticultural Institution, Scottish Horticultural Research Institute, National Vegetable Research Station, Reading and Nottingham Universities, Wye College, Ditton Laboratory, the N.A.A.S., the Transvaal and the West African Cocoa Research Institute. The list of subjects is a wide one; there are papers on rootstock/scion relations, pruning, propagation and nutrition of various fruits; citrus rootstocks; pear viruses; apple sawfly and winter moth; fruit development in relation to plant hormones; weedkillers; the effects of water regimes on tomatoes and lettuces; blindness in cauliflower; factors affecting the flowering of raspberries and chrysanthemums; induced polyploidy in *Theobroma cacao*.

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